BRENT WILEY, *Editor*

T. J. ESS, *Associate Editor*

JAMES D. KELLY, *Advertising Manager*

BOARD OF DIRECTORS

PRESIDENT
WILLIAM A. PERRY
Superintendent Electrical and Power Departments
Inland Steel Company
Indiana Harbor, Indiana

1ST VICE-PRESIDENT, THOMAS E. HUGHES, *Superintendent of Maintenance*, Carnegie-Illinois Steel Corporation, Duquesne, Pennsylvania

2ND VICE-PRESIDENT, FRANK E. FLYNN, *District Manager*, Republic Steel Corporation, Warren, Ohio

TREASURER, C. L. McGRANAHAN, *Assistant General Superintendent*, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania

SECRETARY, J. L. MILLER, *Assistant Chief Combustion Engineer*, Republic Steel Corporation, Cleveland, Ohio

PAST PRESIDENTS: JULIUS A. CLAUSS, *Chief Engineer*, Great Lakes Steel Corporation, Ecorse, Michigan

C. CLARKE WALES, *Vice-President*, Hamilton Bridge Company, Ltd., Hamilton, Ontario, Canada

HONORARY DIRECTORS: JAMES FARRINGTON, *Electrical Superintendent*, Wheeling Steel Corporation, Steubenville, Ohio

A. C. CUMMINS, *General Superintendent*, Youngstown District, Carnegie-Illinois Steel Corporation, Youngstown, Ohio

WALTER H. BURR, *Electrical Superintendent*, Lukens Steel Company, Coatesville, Pennsylvania

DIRECTOR-AT-LARGE, P. F. KINYOUN, *Combustion Engineer*, Bethlehem Steel Company, Lackawanna, New York

DIRECTORS: FREEMAN H. DYKE, *Superintendent Blooming, Bar, and Hot Strip Mills*, Wheeling Steel Corporation, Steubenville, Ohio

A. R. DIBBEN, *Assistant Electrical Superintendent* Youngstown Sheet and Tube Company, East Chicago, Indiana

GEORGE C. PFEFFER, *Superintendent of Power*, Florence Pipe Foundry and Machine Company, Florence, New Jersey

W. J. WILSON, *Chief Electrician*, American Cast Iron Pipe Company, Birmingham, Alabama

I.N. TULL, *Electrical Superintendent*, Republic Steel Corporation, Cleveland, Ohio

STEPHEN M. JENKS, *General Superintendent*, Gary Works, Carnegie-Illinois Steel Corporation, Gary, Indiana

L. J. GOULD, *Assistant Chief Engineer of Construction*, Bethlehem Steel Company, Bethlehem, Pennsylvania

R. S. SHOEMAKER, *Lubrication Engineer*, American Rolling Mill Company, Middletown, Ohio

C. H. WILLIAMS, *Assistant Chief Engineer*, Pittsburgh District, Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania

Managing Director
BRENT WILEY
Empire Building, Pittsburgh, Pennsylvania

IRON AND STEEL ENGINEER

JULY • 1941

VOL. XVIII NO. VII

In This Issue

Regulating Devices—By C. R. Hanna, Manager, Electro-Mechanical Division, Research Laboratories; and R. H. Wright, Industry Engineering Department, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania 29

Discussion: Regulating Devices—Presented by C. Wasserman, G. E. Stoltz, H. B. Peck, H. H. Angel, and C. R. Hanna.... 37

Hardening of Inside Diameters by Inductive Heat Treatment—By H. E. Somes, Chief Engineer, Budd Induction Heating Company, Inc., Detroit, Michigan..... 39

Discussion: Hardening of Inside Diameters by Inductive Heat Treatment—Presented by C. C. Levy, E. I. Pollard, E. H. Hollenback, H. E. Somes, A. T. Ruttencutter, J. S. Murray, Walker Anderson, G. E. Stoltz, J. R. Adams, Wray Dudley, P. H. Brace, Newell Hamilton, M. R. McConnell, R. E. Louden, C. S. Bullion, and S. L. Goodale..... 45

Welded Open Hearth Auxiliaries—By C. C. Keyser, Welding Supervisor, Bethlehem Steel Company, Steelton, Pennsylvania..... 52

Discussion: Welded Open Hearth Auxiliaries—Presented by A. W. Steed, C. C. Keyser, L. J. Gould, and H. C. Boardman 57

Diesel Switching Equipment for Steel Plants—By E. M. Smith, Assistant Sales Manager, Electro-Motive Corporation, LaGrange, Illinois..... 59

Discussion: Diesel Switching Equipment for Steel Plants—Presented by I. N. Tull and A. W. Steed..... 63

Lubrication in Its Relation to Maintenance—By C. W. Phillips, General Master Mechanic, Cleveland District; and R. A. Barta, Lubrication Engineer, Republic Steel Corporation, Cleveland, Ohio..... 64

Discussion: Lubrication in Its Relation to Maintenance—Presented by S. F. Kitlica, R. A. Barta, F. D. Johnson, Maurice Reswick, C. E. S. Eddie, C. W. Phillips, Herman Berry, D. N. Evans, and C. R. Hand..... 70

Latest Design and Equipment for the Industry..... 73

Meet the Equipment Manufacturer..... 88

Items of Interest..... 94

Tentative Program for A.I.S.E. Annual Convention and Iron and Steel Exposition..... 100

Index to Advertisers..... 22

Published Monthly by

ASSOCIATION OF IRON AND STEEL ENGINEERS

Entered as second-class matter January 25th, 1924, at Pittsburgh, Pa., under the Act of March 3rd, 1879

Statements and opinions given in articles and papers appearing in "Iron and Steel Engineer" are the expressions of contributors, for which the Association of Iron and Steel Engineers assumes no responsibility.

Copyright, 1941, The Association of Iron and Steel Engineers

Single Copy Foreign Prepaid $2.00 Single Copy $1.50

Subscription price in U. S. & Canada.....$ 7.50 per year

Subscription price in foreign countries.....$10.00 per year

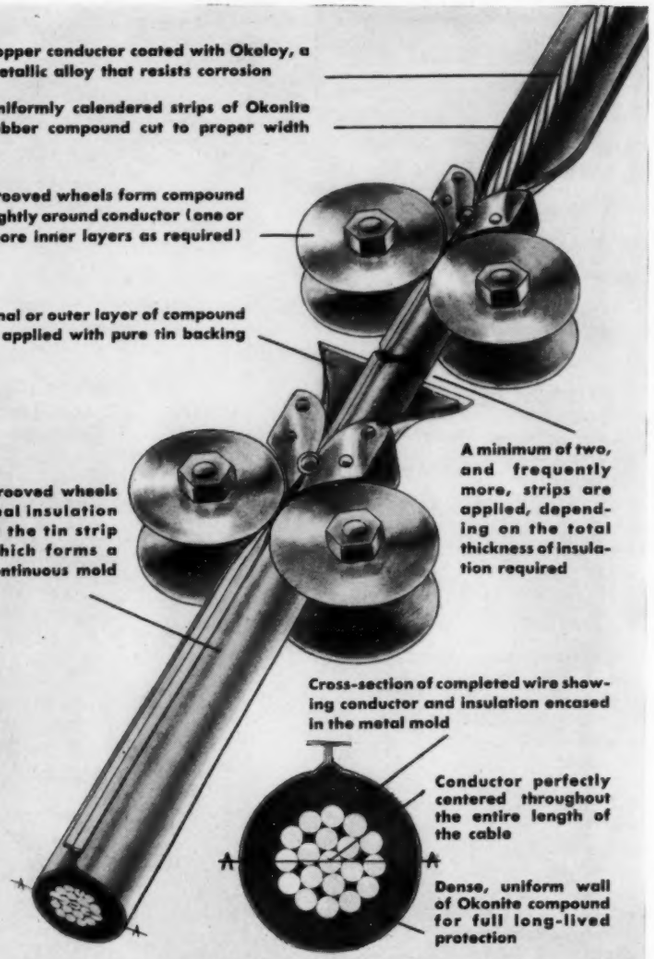
PLASTIC BINDING U. S. PATENT NO. 1970285 LICENSE NO. 58

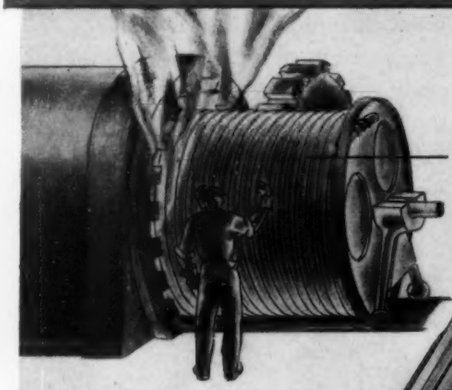
ADVERTISING PAGES REMOVED

OKONITE
Insulation is Applied by This EXCLUSIVE PROCESS

Okonite wires and cables have always been distinguished for long life, exceptional electrical characteristics, high insulation density and perfect centering of conductors.

Of utmost importance to the attainment of these results is Okonite's strip-insulating process by which the insulation is wrapped around the conductor and sealed in a continuous metal mold during vulcanization. For nearly 60 years we have made Okonite insulation this way and for 60 years Okonite has been compiling unequalled records for unfailing performance under severest service conditions.


Copper conductor coated with Okoloy, a metallic alloy that resists corrosion
Uniformly calendered strips of Okonite rubber compound cut to proper width
Grooved wheels form compound tightly around conductor (one or more inner layers as required)
Final or outer layer of compound is applied with pure tin backing
A minimum of two, and frequently more, strips are applied, depending on the total thickness of insulation required
Grooved wheels seal insulation in the tin strip which forms a continuous mold
Cross-section of completed wire showing conductor and insulation encased in the metal mold
Conductor perfectly centered throughout the entire length of the cable
Dense, uniform wall of Okonite compound for full long-lived protection



Vulcanization takes place under high temperature and pressure. The metal mold insures even density and heat distribution

The Single Ridge is the hall-mark of this exclusive method of cable manufacture—LOOK FOR IT

The tin mold is removed after vulcanization and the insulated conductor is ready for a series of complete electrical and mechanical tests before application of coverings

5 FOUNDATIONS OF OKONITE QUALITY

1. Made only with Up-river Fine Para rubber carefully washed and dried
2. The Okonite formula is proved by long use rather than accelerated tests
3. Conductors perfectly centered by the Okonite strip-insulating process
4. Uniformly vulcanized under pressure in a continuous metal mold
5. Thoroughly tested and inspected throughout the manufacturing process

Okonite's Okoloy coating on conductors eliminates corrosion

THE OKONITE COMPANY
Passaic, New Jersey
Offices in principal cities

OKONITE Insulated Wires and Cables

REGULATING DEVICES

By C. R. Hanna and R. H. Wright

This paper was presented before the Philadelphia Section of the A.I.S.E. January 4, 1941. Mr. Wright is in the Industry Engineering Department of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania, while Mr. Hanna is manager of their Electro-Mechanical Division.

▲ THE steel industry makes use of almost every type of regulating device which has been developed for industrial applications. Because of the almost endless variety of such devices it would not be practicable to undertake, in a single paper, a complete discussion of all the regulating devices now in use. Therefore, this paper will deal chiefly with electrical regulating devices suitable for use in steel plants and associated industries.

There are certain characteristics which are common to all regulating devices. First of all, all regulators are amplifiers. A small deviation in the quantity being regulated is made to produce a large corrective effect to reduce the deviation. In general, the greater the amplification the more accurate the device will be. However, in most cases the amplification is limited by a second property which is common to all regulating systems. This property is the unavoidable time delay which occurs between the initiation of a correction and the completion of the correction. In practically all cases the presence of this delay will cause undesirable oscillation or even hunting if too high accuracy is attempted. This third characteristic, the tendency for oscillation or hunting, is another property which must be dealt with in designing any regulating system, particularly if the system involves rotating apparatus. Therefore, to produce a successful regulating system it is necessary to secure a nice balance between the amplification used and the speed of response of the system.

It will be evident that there is a great similarity between electrical and mechanical regulators, particularly in matters of amplification, time delays, and need for stabilization. Because of this similarity and because many regulators use a combination of both electrical and mechanical elements, a discussion of electrical regulators will serve to illustrate the general principles of all types of regulators.

Any regulating system consists of a control element, usually considered as the regulator and which might be called the detector; a means for applying the corrective force which might be called the amplifier, and a stabilizing device. A part of the amplification may be obtained from the detector. The stabilizer may be a separate device or stability may be secured through an inherent characteristic of the system such as a tendency to droop with load. In a typical system for regulating voltage there will be a regulator which is responsive to voltage, a variable voltage exciter in the main field circuit which can be made to produce the corrective effect and a damping transformer to insure stability. The sensitivity or accuracy of the regulator will determine the amount of voltage variation required to initiate a correction. Sensitivity is usually between plus or minus ¼ per cent and plus or minus 3 per cent. After a correction is initiated, the time for completion will depend on the speed with which the exciter field and main generator field can be made to respond. Whether the correction proceeds just far enough or so far as to cause an overswing will be determined by the operation of the damping device. So, for a given degree of sensitivity, the regulator itself has little or no control over the time required to complete a correction. It is for this reason that it is necessary to study the response characteristics of the machine field circuits when designing a regulating system.

When a sudden disturbance arises in the system, the regulated quantity may depart considerably from the desired value. Correction will take place in a time which is determined by the delays of the system. The ultimate value will be within the sensitivity range of the regulator. Therefore, aside from the relatively large momentary departures, sensitivity and accuracy are the same.

Damping devices are made to be responsive to the rate of change in the regulated quantity or some quantity proportional to it. The mechanical dashpots used with some types of regulators operate in this manner and will serve to illustrate this principle. A dashpot is attached to the regulator arm by a spring so that the piston does not interfere with small or slow movements of the arm. When there is a sudden movement of the arm due to a large change the dashpot restrains the movement and prevents an overswing. A damping transformer does the same thing electrically with the advantage that its adjustment is permanent and there is no variable mechanical friction, and the design can be calculated to suit the characteristics of the system, thus practically eliminating field adjustments.

Therefore, the essential parts of a good regulating system are:

a. A regulator or detector with sufficient sensitivity to detect small changes in the regulated quantity. The

regulator will include contacts or other means for transmitting its impulses to the device which supplies the corrective effect.

b. A device for applying the corrective effect in response to impulses received from the regulator. In an electrical regulator this may be a set of contacts, a grid controlled or ignitron rectifier, an exciter, a booster, a rheostat or a combination of two or more elements.

c. A damping device. In an electrical regulator this may be a dashpot, damping transformer or a separate circuit which reacts on the regulator.

For convenience in discussion, electrical regulators may be divided into three general classes as follows:

a. Regulators for voltage and current.

b. Speed regulators.

c. Position regulators.

This classification is arranged in the ascending order of the difficulties involved in the design. Regulation of voltage and current involves the detection of variations of these quantities and changes in field current to correct for the variations. To regulate speed it is necessary to translate the variations into a form in which they can be detected by a regulator and to change a field current which in turn produces a corrective torque. To regulate the position of one rotating device relative to another it is necessary to translate variations in position into a form in which they can be detected and to synchronize the speeds and hold the relative angular positions.

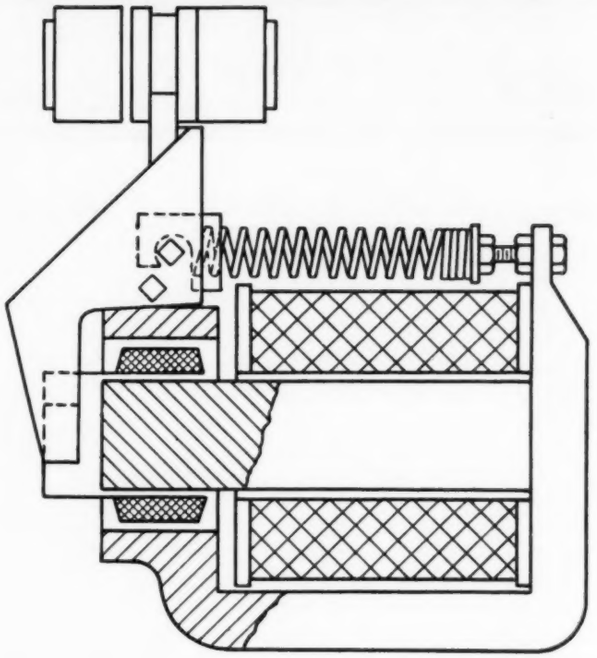


Figure 1—Vibrating regulator for heavy duty steel mill applications.

VOLTAGE AND CURRENT REGULATORS

When regulators are mentioned to the average electrical engineer he may think, first of some form of vibrating regulator for controlling voltage or current. A great many vibrating regulators of the Tirrill type are in operation, particularly for regulating the voltage of turbo generators. Such regulators consist of a control coil, a set of master contacts which are kept in continuous vibration by a separate coil or by pulsations introduced into the control coil, and a set of vibrating relays which control the field current of the generator exciter. Regulators of this type are kept in balance by dashpots and counterweights. Tirrill regulators perform very well but require considerable attention.

The present tendency is either to use some other type of regulator for voltage regulation or to simplify the design so as to reduce the amount of attention and maintenance. However, the vibrating regulator may never be superseded completely. For example, hundreds of thousands of automobiles have vibrating regulators as parts of the electrical systems.

A typical example of a more recent design of vibrating regulator is shown in Figure 1. This regulator is constructed very much like a dynamic loud speaker except that the vibrating coil is connected to contacts rather than to a sound cone. Regulators of this type have three coils. Two coils are stationary and are placed on an iron core in the magnetic field circuit. One stationary coil is the exciting coil and is connected to a constant potential source. The other stationary coil is frequently used as the tickler or anti-hunting coil and when so used is usually connected to the field terminals of the main machine or to the armature leads of the exciter or booster. In more recent applications a damping transformer is connected in the exciting coil circuit and the tickler coil is not used. The third coil is suspended in the air gap in the magnetic circuit and is used to actuate the main contacts. This coil is connected to the circuit being regulated.

Regulators of the type just described are used in connection with d-c. machines to regulate either current or voltage. Applications include regulation of bus voltage in strip mills, regulation of current input to tension reel motors and control of current and voltage in reversing equipments. This type of regulator is quite sensitive, operates rapidly and can be easily adjusted over a wide range. For many applications no dashpot is necessary. A solid metal cover is used for enclosure.

Special regulating equipment has been developed for a number of applications. A typical example is the arc furnace regulator which is a rheostatic type current regulator with special features to make the furnace completely automatic. The operation of an arc furnace regulator is similar to that of a simple indirect acting rheostatic regulator in that the control element regulates the current by shifting the position of the furnace electrodes. As shown by the photograph in Figure 2, one control element and one electrode motor and control are provided for each phase.

Figure 3 shows schematically the connections for control of one electrode. The regulator has two coils; one of which is a current coil carrying a current proportional to the arc current and the other a voltage coil on which is impressed the voltage between the electrode and ground. The movable cores of the two coils are suspended on opposite ends of a balanced arm. When the furnace is not in service the electrodes are raised and no current is flowing and both regulator contacts are open. When power is first applied only the voltage coil of the regulator is energized, its impressed voltage being

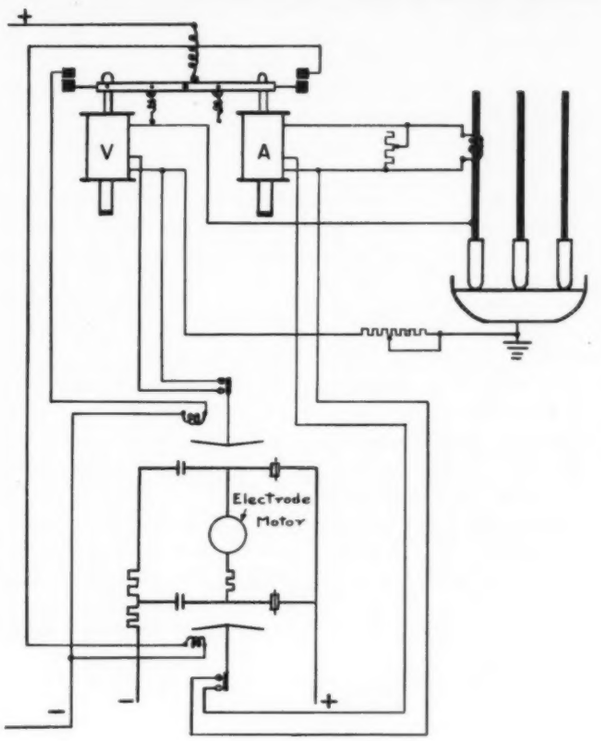


Figure 3—Schematic diagram of arc furnace regulator.

the full open circuit voltage from the electrode to ground. This voltage causes the core in the voltage coil to rise and close its contacts and the motor begins to lower the electrode. The other electrodes are being lowered at the same time. As soon as two electrodes touch the charge the current coil of the regulator is energized and the electrode motor reverses and raises the electrode until the pulls of the current and voltage coils balance. Any disturbance of the equilibrium between the current and voltage coils will cause contacts to close to lower or raise the electrodes. Auxiliary contacts which shunt out portions of the associated regulator coil are provided on the motor contactors. This causes the regulator arm to vibrate when the arc current is within about 15 per cent of the desired value, thus eliminating overshooting or hunting.

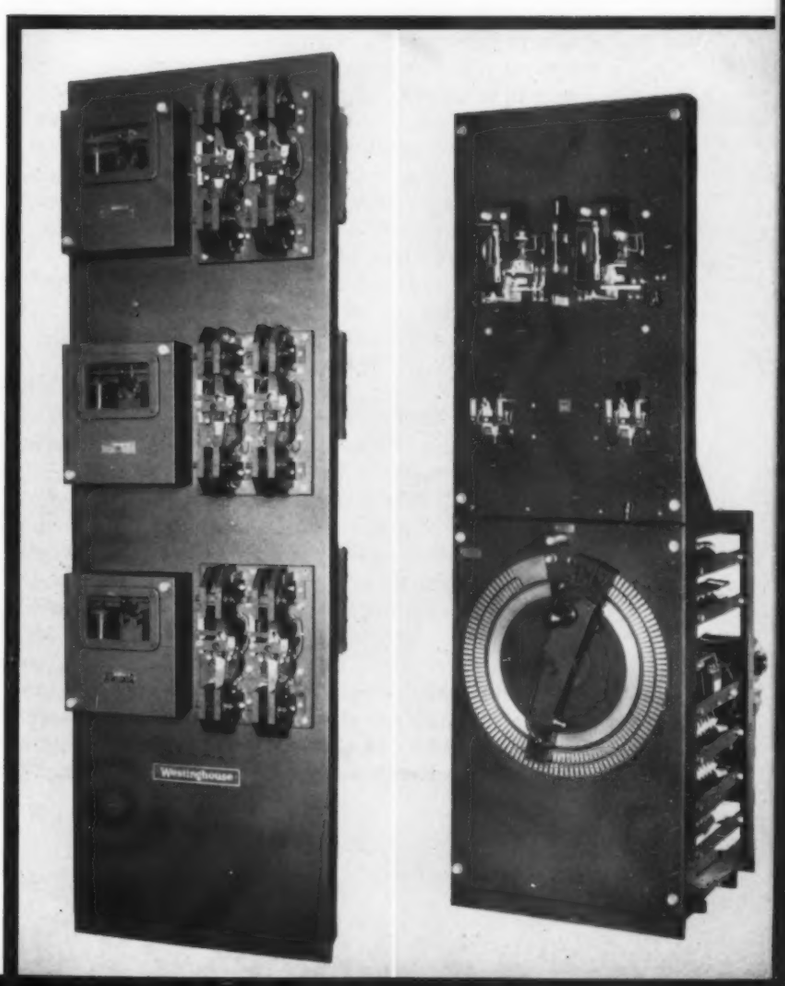
Rheostatic regulators have been used for many years and the field of application is being extended by recent developments. In the most simple form a rheostatic regulator consists of a motor operated rheostat in the field of the machine being controlled and a simple control element with contacts for running the rheostat motor in either direction. The control element usually has a sensitivity of plus or minus 1 per cent. Such a regulating system can be used for controlling current or voltage in a circuit which operates under steady conditions. For example, the current output of a low voltage d-c. generator which supplies a group of electrogalvanizing cells connected in series can be held at a constant value with varying numbers of cells in the circuit with such a system. The voltage of d-c. generators feeding into a constant voltage network is often regulated in the same way. Automatic substations for 230 volt steel mill systems are often provided with a rheostatic regulating system which serves two functions. Under normal load the regulator maintains constant voltage at the generator terminals. When there is an overload on the system, usually brought about by loss of one or more generators at some point in the system, the regulator reduces the voltage of its generator until the current output is about 150 per cent of the generator rating. If the overload is removed in a short time, the regulator brings the voltage back to normal. If the overload persists for more than a predetermined time, a thermal relay recalibrates the regulator for a lower safe current.

A modification of this scheme is used for controlling mercury arc rectifiers. The rectifier is provided with a motor operated phase shifter by which the d-c. output voltage can be adjusted. The voltage regulator operates the phase shifter in the same manner that it would operate a motor operated rheostat for a generator and the same operating features are obtained.

Rheostatic regulators can also be used to regulate the voltage of turbo generators or to control the excitation of a synchronous motor or condenser to improve the voltage regulation at the end of a transmission line. An indirect acting type of regulating equipment for this service is shown with its control element in Figures 4

Figure 2—*(left)* Arc furnace regulator.

Figure 4—Indirect acting rheostatic regulator with high speed contactors.



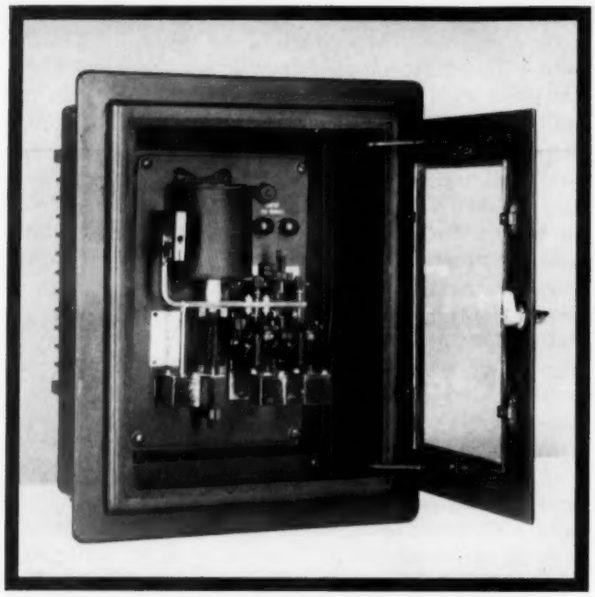


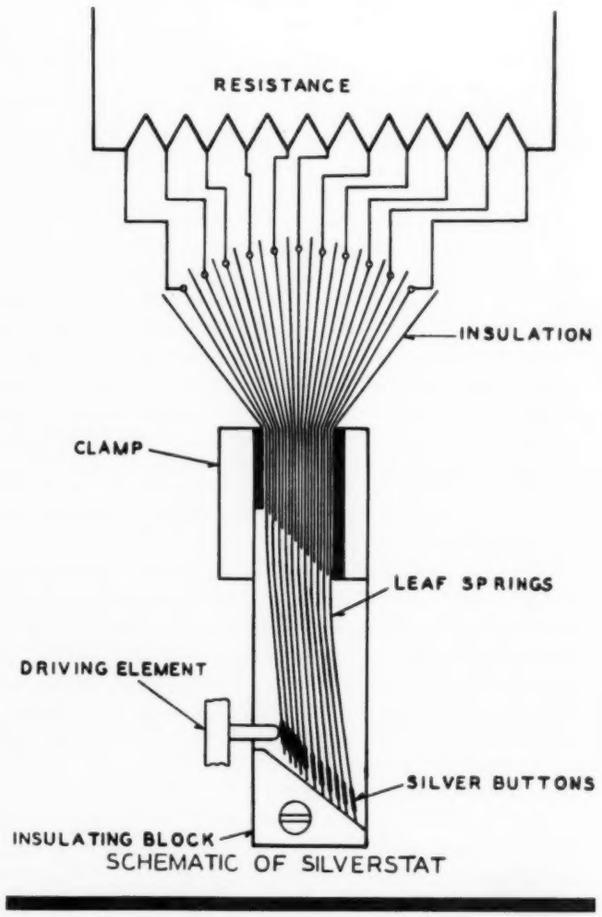
Figure 5—Control element of indirect acting rheostatic regulator.

and 5. The complete equipment consists of a motor operated faceplate connected in the field of the generator exciter, blocks of resistance in the field circuit which can be cut out or inserted and a control element with two sets of contacts. For small deviations from the normal voltage the normal response contacts of the control element actuate the motor operated faceplate. For large deviations the quick response contacts actuate high speed contactors in the field circuit to effect quickly a large change in field current. At the same time the normal response contacts start to move the faceplate arm to a new position. The lever arm of the control element is normally at rest and there are no continuously rotating or vibrating contacts. The contacts are arranged so that when either the normal response or quick response contacts on the regulator arm move, the stationary contacts are withdrawn. This gives a step by step movement of the rheostat for small voltage changes or causes the quick response contactors to flutter rapidly for larger changes. Regulators of this type are very fast in operation and the control element has a sensitivity of plus or minus ½ per cent.

Recently a direct acting rheostatic regulator has been developed. This regulator has a control coil which is mounted on a C-shaped iron core and an armature arranged to move in the constant air gap of the magnetic circuit. The armature has a frictionless mounting without wearing parts and the magnetic pull on the armature is balanced by a heavy coil spring. Figure 6 shows a schematic arrangement of the elements of this regulator. A number of silver buttons are mounted so that they can be actuated in sequence by movement of the armature. Each button is carried on the free end of a flat leaf spring. The free ends of the springs normally rest against a block of insulating material. The other ends of the springs are clamped together with insulation between them. The fixed end of each leaf spring is connected to a tap on a regulating resistance in the field of the exciter. The silver buttons are separated and the resistance is a maximum when the driving member is at the left hand of its travel, as located in the figure. A movement to the right of only a small fraction of an inch will close the gaps between all the buttons in sequence and give minimum resistance. The regulator operates as a semi-static device and moves only when a correction is necessary. Stability is obtained by the use of a damping transformer.

Figure 7 is a diagram of connections for a direct acting rheostatic regulator used to regulate the voltage of an a-c. generator. The control coil of the regulator is energized from the generator leads through a potential transformer and a rectifier. The generator exciter is self excited and the regulating resistance is in the shunt field circuit of the exciter. The primary of the damping transformer is connected across the terminals of the exciter. The secondary of the damping transformer is in series with the regulator control coil circuit. Under steady condition the damping transformer of course has no effect. The damping transformer connections are such that any sudden change in the exciter voltage, brought about by movement of the regulator, sets up a transient voltage in the transformer secondary which

Figure 6—Schematic arrangement of a direct acting rheostatic regulator.



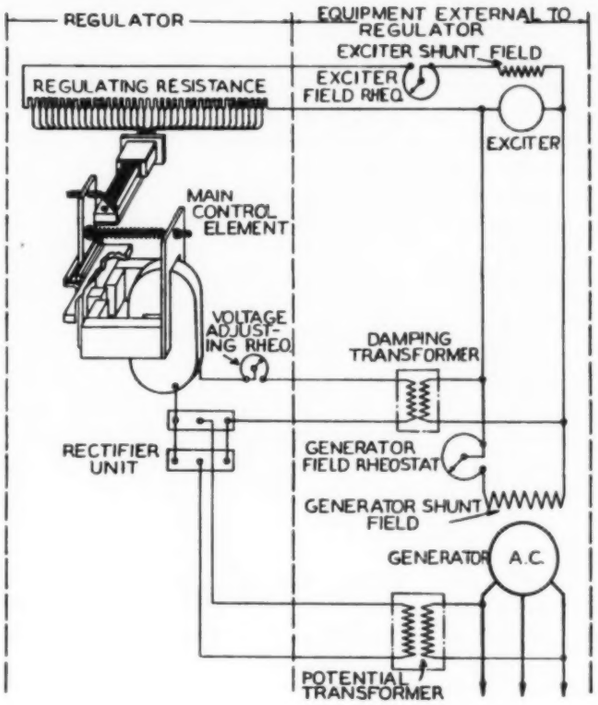


Figure 7—Diagram of connections for a direct acting rheostatic regulator used for regulating voltage of an a-c generator.

tends to oppose the movement which caused the change. The effect is the same as that of a frictionless dashpot and very effective damping is thus secured. The correct damping transformer characteristics can be calculated very accurately.

When the generator exciter is large it is possible to use one or more pilot exciters so as to limit the current to be handled by the regulator. For each pilot exciter a damping transformer is added and the secondaries are connected in series. Systems consisting of four machines; a main generator, main exciter and two cascaded pilot exciters have been tried out experimentally and found to be satisfactory. The proper characteristics for the damping transformers for any number of cascaded exciters can be calculated very accurately.

Regulators of this type are inherently adapted for use as current or voltage regulators. The tendency is to extend its field of application. One rather difficult application for which they have been found to operate successfully is the regulation of the voltage of single phase spot welding generators. One application is on a 240 volt single phase generator which supplies four welders which can be operated in any random order. Although the inherent regulation of the generator from no load to full load is over 60 volts, the voltage under the worst operating conditions does not vary more than plus or minus 8 volts and there is no tendency for resonant oscillation under any condition.

Electronic voltage regulators are sometimes used on the same types of applications as the electro-mechanical regulators previously described. Electronic regulators are in reality voltage matching regulators in that the voltage of the generator is compared with some standard potential source, usually a high voltage dry battery. The excitation for the generator is drawn from an a-c. source and rectified. Field current for machines of fairly large size can be handled direct. For larger machines the regulator operates through a separate exciter. An electronic regulator has a sensitivity of plus or minus ¼ per cent and acts very quickly, but the overall response is determined by the characteristics of other parts of the system, just as in the case of other types of regulators previously described. The electronic regulator is described more in detail under speed regulators.

SPEED REGULATORS

A speed regulator is considered as a self contained device which will regulate the speed of a d-c. motor with no reference to the speed of any other machine. This is to distinguish it from a speed matching regulator which is a position regulator used to maintain a definite relation between the speeds of two machines.

Due to the excellent inherent regulation which can be obtained with large d-c. mill motors, very few occasions arise for using speed regulators on main roll drives. In one case a speed regulator was used with a

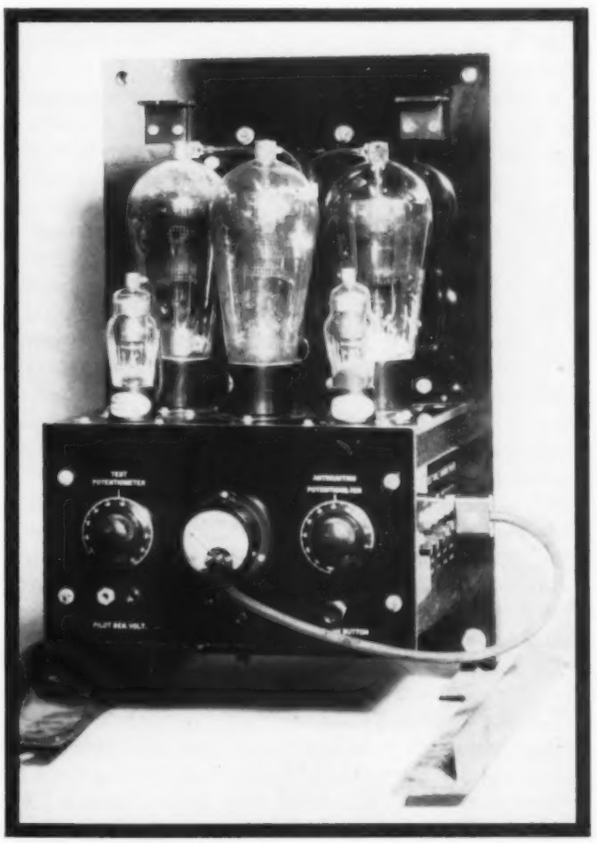


Figure 8—Electronic speed regulator.

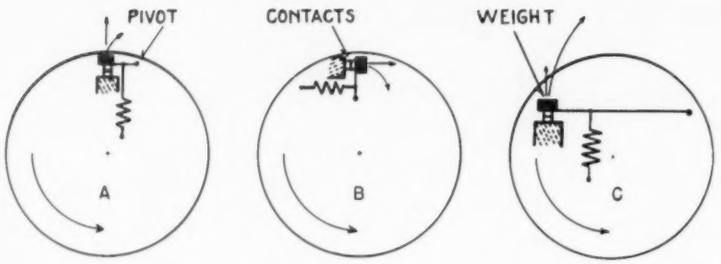


Figure 9—Schematic arrangements of the elements of a speed governor.

motor which was subject to excessive voltage variations due to its being on the end of a long overloaded line. The regulating system used consisted of a d-c. pilot generator geared to the motor, voltage regulator similar to that shown in Figure 1 and a booster exciter in series with the motor field circuit. The pilot generator is operated with a highly saturated field so that its voltage is not affected by changes in excitation voltage. The regulator armature coil is connected to the pilot exciter and the regulator contacts control the booster exciter in the motor field circuit. The regulator tends to maintain constant voltage at the terminals of the pilot generator and does this by controlling the speed of the motor. A system of this type is sometimes useful for improving the regulation of a small auxiliary motor which has poor inherent regulation and which operates on fluctuating voltage.

Synchronous tie signalling systems operate best on 60 cycles. In 25 cycle plants it is the usual practice to install a small d-c.—a-c. motor-generator to supply this circuit. Where the synchro-ties are large and transmit considerable torque it is desirable to maintain the a-c. frequency within fairly close limits. In one case the d-c. supply voltage fluctuated so widely that a speed regulator had to be used. A system as described above was used.

A diesel engine plant in Detroit sometimes operates entirely on power received from dynamometers and other d-c. generators used for testing engines. This power is received at two voltages and is converted to 60 cycles by a three unit, 1500 kw., d-c.—a-c. motor-generator. The frequency must be regulated within ½ cycle to permit the use of electric thickness gauges. This is done by a speed regulator actuated from a specially designed d-c. pilot generator which is coupled to the motor-generator. The regulator is of the indirect acting rheostatic type with high speed quick response contacts as described for regulation of turbo generators.

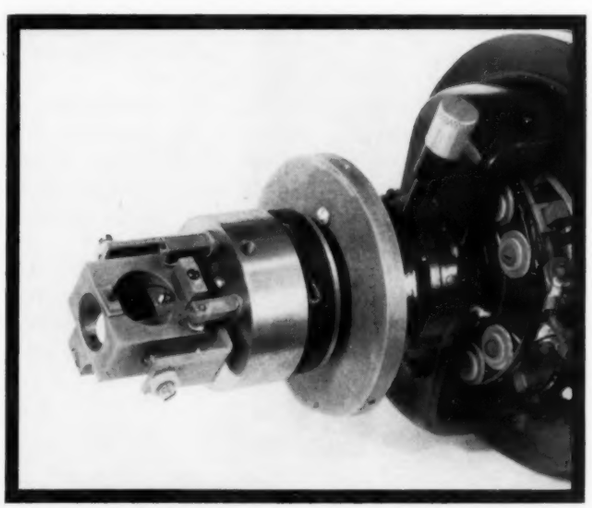
An electronic speed regulator can be made which operates on the same general principle and speed regulators of this type have been used for paper mill single motor drives for a number of years. A single motor paper mill drive consists of a d-c. motor and a variable voltage generator. The drive may operate over a 10 to 1 speed range entirely by voltage control or with a combination of voltage control and motor field control. Corrections for variations in speed are made by changing the generator voltage and the regulator actually operates as a broad range voltage regulator.

The regulating system consists of a d-c. pilot generator which is driven by the motor, a variable voltage exciter for the main generator, an electronic regulator and a 45 volt radio B battery to supply the reference voltage. Figure 8 shows a regulator as used for this purpose. The regulator has three grid controlled rectifier tubes which rectify three phase a-c. for supplying the field of the generator exciter. The rectifier tubes are controlled by two small tubes which are connected so as to be affected by any voltage differential between the pilot generator and the battery. Stability is obtained by means of a small capacitor which is connected so that any sudden variation in the grid voltage of the control tubes will be opposed. This effect can be adjusted by a small rheostat. This regulator will continue to function even if one rectifier tube or one control tube fails. In the base of the regulator there is a complete test kit with plug jacks by which the tubes can be given periodic tests.

Recently considerable effort has been given to the study of electric speed governors which can be mounted on the shaft of the motor to be regulated. The ordinary flyball centrifugal governor initiates a correction only after a change in speed occurs, so a purely centrifugal governor with electric contacts would give poor regulation. A properly designed speed governor will be affected not only by change in speed but by the rate of change of speed. In other words an effective speed governor anticipates a change in speed as soon as a deviation starts. Such a governor does not require any external stabilizing device.

The general principle of electric speed governors is shown in Figure 9. At *A* is an element which is mounted so that it can move only in a radial direction. The contact pressure is affected only by the speed and a

Figure 10—Speed governor with elements arranged as shown at C, Figure 9.



device built along these lines would perform like a flyball governor. The element at *B* is mounted so that it can move only in a tangential direction. The contact pressure is affected only by acceleration. The element at *C* is mounted so that the contact pressure is affected by both acceleration and changes in speed. Simple elements as shown in this figure are affected by gravity if mounted on a horizontal shaft unless the parts are balanced against gravity effect. At each revolution the effect of gravity on the weight would change the contact pressure and the contacts would tend to vibrate and the regulation would be affected. It is not necessary in a device of this type for the contacts to move appreciably in order to exercise a regulating function under steady state conditions. A slight hovering vibration is all that is required. In fact excessive vibration of the contacts is not beneficial as the vibration can be overcome only by an increase in average pressure, requiring a corresponding change of speed. Therefore, in designing a rotating speed governor it is desirable to have a device which preserves the principle of high amplification and which has an inherent stabilizing influence.

A device which has been developed is shown in Figure 10. The steel disc with the wide face is a flywheel which is mounted on ball bearings on the motor shaft extension. The two arms which are attached to the flywheel are of insulating material and carry contacts on the outer ends. Only one of the contacts is used in the control circuit, the other being used to provide the reaction for the active contact. A second set of contacts is carried on a gravity balanced speed responsive cage member mounted in a U-shaped frame which is attached solidly to the motor shaft. This cage member is supported on ball bearings on an axis perpendicular to the motor shaft. The balance against gravity prevents unwanted vibration of the contacts due to rotation. There are two weights which give rise to a centrifugal couple tending to rotate the cage about its pivot axis when the entire assembly is rotating. This tendency to rotate is restrained by a spring. The speed for which the governor regulates is determined by the adjustment of the spring. The contacts as shown in Figure 11 are connected to shunt a resistance in the field circuit of the motor.

When the motor is running at the correct speed a hovering condition is established between the contacts so that the contact pressure is just sufficient to hold the correct motor field current. A sudden change in load tending to cause a change in speed disturbs the contact pressure due to the effect of the flywheel and a correction is made. The flywheel is the stabilizing element of the system and its inertia is made to fit the time delay characteristics of the system. If it is necessary to use an exciter to handle the motor field current, the proper flywheel can be calculated to take care of the increased time delay.

The unique feature of a speed regulator of the type just described is not that its performance is materially different from that of other types of speed regulators, but that it operates on a different principle and uses an entirely different stabilizing means. Such electric governors are useful for regulating machines which operate at only one speed.

The question naturally arises, that if rotating machines themselves are amplifiers why not use them

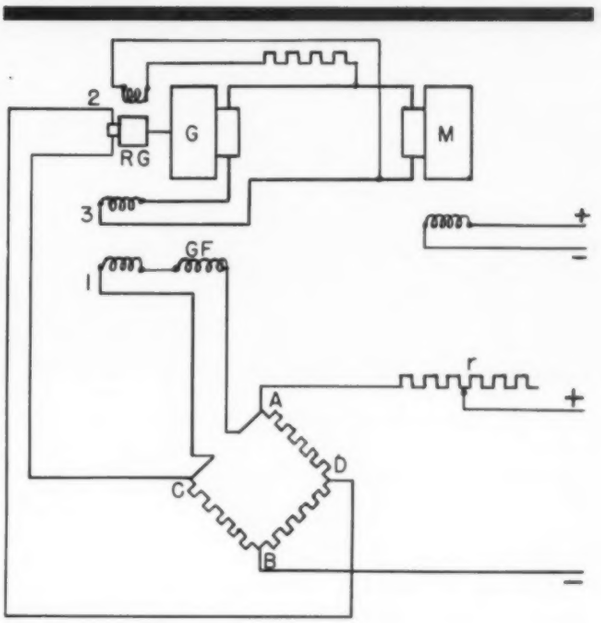


Figure 11—Schematic diagram of connections for a rotating regulator.

exclusively for the regulating function? The answer is that they can be used as regulators and have been so used for a good many years. A simple example of a rotating regulator is an exciter with two differentially connected field windings and with one field supplied from a fixed reference voltage and the other winding supplied from the circuit which is to be regulated. It is readily seen that if each of the two field windings has considerable strength, a small percentage variation in one winding will produce sufficient resultant excitation to give a usable armature output voltage for control purposes. Such a scheme has been used for single motor paper mill drives which are made to operate over a 6 to 1 speed range. These drives consist of an adjustable speed d-c. motor and a variable voltage generator. The rotating regulator is a small constant speed generator with two differentially connected shunt fields. One field is connected to a pilot generator which is driven by the main mill motor. The other field is excited from a constant potential source. The armature output voltage of the regulating generator is applied so that it regulates the excitation of the main generator to maintain constant speed. Suitable rheostats make it possible to change the regulator setting.

Another form of rotating regulator is shown in Figure 11. The chief function of the system shown in this figure is to insure stable operation over an extremely wide range of speed. This system is essentially the same as described for paper mill drive except that IR drop compensation has been added to avoid stalling at very low speeds. This circuit has been widely applied during the last ten years to skip hoists, planers and high speed elevators, one of the most notable examples being the elevators at Radio City.

As shown in Figure 11, the complete system consists of a motor *M*, a variable voltage generator *G*, a regulat-

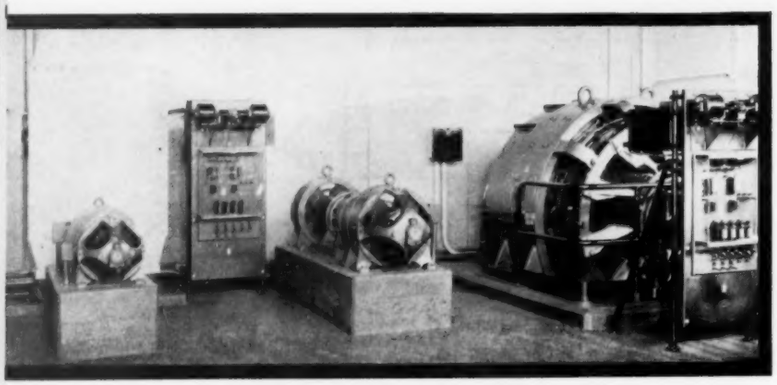


Figure 12—Speed matching regulators.

ing generator *RG* and a bridge circuit *ABCD*. Exciting current from an external source is introduced into the bridge circuit at points *A* and *B* through the adjustable resistance *r* which may be adjusted by a rheostat or contactors. The adjustment of resistance *r* determines the speed of motor *M*. The regulating generator is connected to the bridge circuit at *C* and *D* so that its output current will either be added to or subtracted from the external source, depending on the corrective effect which is required. The function of the regulating generator is to maintain the speed at the value corresponding to the current flowing in resistance *r*.

Field 1 of the regulating generator is in series with the shunt field winding of the main generator and carries the same current. It produces a voltage in the regulating generator which assists the main generator field. Field 2 opposed field 1 and provides the speed sensing feature. Field 3 assists field 1 and its strength is adjusted so that at any motoring load it causes the regulating generator to boost the voltage of the main generator by an amount equal to the resistance drop in the main armature circuit. This arrangement makes it possible for the motor to operate with heavy load at very slow speeds with no tendency to stall. If, on the other hand, the external excitation has been reduced to a very low value to secure a very low light load motoring speed and the residual voltage of the generator tends to give a higher speed than is desired, field 2 will be stronger than fields 1 and 3 and the voltage of the regulating generator will reverse and will reduce the main generator voltage. If under this condition the load current increases due to uneven load, field 3 will tend to raise the voltage and maintain the speed. If the load is overhauling, the motor becomes a generator and its terminal voltage rises and the current in the armature and in field 3 reverses. Fields 2 and 3 then oppose field 1 and weaken the generator field, thus increasing the regenerative current and limiting the speed.

By suitable modification of design, rotating regulators can be built to perform a number of functions. Where such regulators can be used to advantage, the most consistent performance is obtained by keeping the design as simple as possible. By special construction high amplification characteristics can be obtained in a single machine. However, the same amplification can be obtained by the use of two cascaded exciters of standard construction and the adjustments are not as critical and the operation is inherently more consistent.

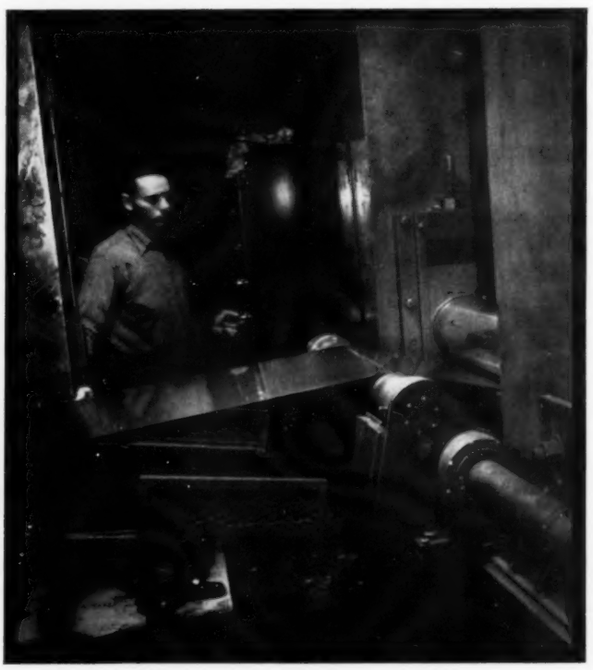
With any type of speed regulator there is always a momentary dip in speed when load is suddenly applied and a momentary rise in speed when the load is released. The magnitude of these transient changes is determined by the inertia and the inductance and resistance of the motor armature circuit. No speed regulator will entirely eliminate this transient but the type of regulator will affect the shape of the transient curve and the oscillations which may follow.

POSITION REGULATORS

An accurate speed matching regulator is a position regulator and is one of the most common examples of a position regulator application. Figure 12 shows an installation of speed matching regulators. This regulator was first developed to match the speed of a 1500 hp., d-c. motor on a rod mill finishing train with the speed of an engine which drove the roughing train.

The regulator shown in this figure consists of two small synchronous motors, a small mechanical differential, a vibrating lever system and a set of shunting relays. One synchronous motor is driven from a pilot generator on the master machine. The other synchronous motor is driven by a pilot generator on the motor which is to follow the master machine. The middle element of the differential to which the synchronous motors are connected mechanically is connected by a light lever arm to the vibrating lever system. Any variation between

Figure 13—Cold strip mill tensiometer.



the relative speed of the regulated motor and the master machine moves the middle element of the differential and changes the position of the vibrating lever system. The shunting relays then apply the corrective effect through a buck and boost exciter in the field circuit of the motor. The action of this system can be made very fast and stable. When load is applied to the regulated motor any point on the surface of the armature merely drops back in phase position just as does the rotor of a synchronous motor. For a recent installation a rheostatic regulator was substituted for the vibrating lever system and shunting relays. The operating range of a regulating system of this type can be adjusted by driving one of the pilot generators through a variable ratio V-belt drive.

A cold strip mill tensiometer is another example of a position regulator. A tensiometer consists of a tension roller which is held at a definite distance above the pass line with a known pressure, thus producing a definite tension on the strip. Any vertical movement of the tension roller is transmitted by a synchro-tie to a regulator which controls the speed of one of the mill motors. This regulator has vibrating contacts and a compound lever system similar to the speed matching regulator shown in Figure 12. The receiver of the synchro-tie is connected mechanically to the lever system of the regulator in such a way that any movement of the receiver changes the position of the vibrating contacts and changes the speed of the mill motor to bring the tension roller to the correct position. Figure 13 shows the mechanism which is installed in the mill.

This brief review of regulating equipment is intended chiefly to show the progress which has been made in the design of regulating devices. A comparatively few years ago practically all automatic regulation was accomplished by the use of some form of Tirrill regulator. At the present time a wide variety of regulating devices is available. Each type of regulating device has its own main field of application although there may be some overlapping of fields. When the proper type has been chosen for a given application the performance may be predicted with a certainty that was not possible in the past. Or in other words, the design and application of regulators has become more of a science and less of an art.

DISCUSSION

PRESENTED BY

C. WASSERMAN, *Assistant to Electrical Engineer,* Consolidated Gas and Electric Light and Power Company of Baltimore, Baltimore, Maryland

G. E. STOLTZ, Manager, Metal Working Section, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania

H. B. PECK, *Assistant to Electrical Engineer,* Consolidated Gas and Electric Light and Power Company of Baltimore, Baltimore, Maryland

H. H. ANGEL, *Electrical Department,* Bethlehem Steel Company, Sparrows Point, Maryland

C. R. HANNA, *Manager,* Electro-Mechanical Division, Research Laboratories, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania

C. WASSERMAN: I would like to know what is the largest capacity machine on which direct acting rheostatic voltage regulators have been applied to date? Also, what is the number of steps that are used in a regulator of this type and is there any information available as to the delay of response of the regulator?

G. E. STOLTZ: There are a number of things involved in the design and selection of regulators and I would suggest that Mr. Hanna give his thoughts on the selection of different types for various applications.

The thing that concerns a manufacturer in regard to regulators more than anything else is to be able to make an installation that will operate with as little attention as possible because a regulator is a device that may require a great deal of attention if not properly applied.

Mr. Wright cited the case of the rheostatic type used in charging cells. The load does not change rapidly on such an application so that the simplest type is satisfactory. On the other hand, if we tried such a type on the reel of a cold mill where rapid changes take place, the action of this type of regulator would be too slow in response. It is important to adapt the particular type to the job it has to do. We always try to select the simplest possible design for the application required.

H. B. PECK: In connection with Mr. Stoltz's remarks concerning picking a specific regulator for a specific job, I should like to ask Mr. Hanna how many operations of the moving contact should reasonably be expected before the contact buttons on the faceplate of a rheostatic-type regulator would need replacement. Information of this sort is important and very helpful if you have a specific application in mind and are endeavoring to choose the type of regulator.

H. H. ANGEL: We have in our plant quite a variety of regulators which serve all kinds of useful purposes. In general, if the regulator requires very much maintenance, we find you might as well get rid of it because when it gets to that stage it isn't of much value to anybody.

We also find that most regulators improve the operation quite a fair amount and make the job just that much nicer in obtaining the ultimate results the operating men require. For example, on voltage regulators, if it becomes necessary to cut one out because it does not work properly, you will find you can operate fairly well without it, but still not as well as should be; and the same thing applies to some other kinds of regulators, but there are places where a considerable hardship results if the regulator is out of commission. We have voltage regulators on a frequency changer, and when they get out of commission the operators have to watch the voltage more carefully and we just do not get the results we should.

In the cold strip and hot strip mills we have the tension regulators on the tension reels, and I know if those regulators are out of commission you can't roll

steel because the tension would vary considerably and you couldn't wind a good coil.

In connection with Mr. Wright's discussion or description of the anticipating device on the governor type regulator, or similar device on the motor whose speed you were trying to regulate, that brings up something I have wondered about, that is, some kind of good anticipating device because there are lots of jobs where you are bound to get the dip in the voltage, or current, or speed, in spite of how well the regulator works, but I imagine if we shoot for some kind of anticipating device it is like hoping to obtain perpetual motion. However, the goal may be obtained by improvements from time to time in the type of regulators used, and their improved sensitivity.

I would like to ask the authors about what percentage of accuracy can be obtained in making the rod mill finishing motor follow the speed of the steam unit which drives other units of the mill. I don't know whether he mentioned speeds that could be obtained, if he did I missed it.

C. R. HANNA: Answering Mr. Wasserman, the largest direct acting rheostatic regulator employs eight stacks of 40 steps each and can carry 20 amperes at 250 volts. This is capable of controlling a 10,000 kva. machine. The delay of the regulator is appreciable, but usually much smaller than the delay of the exciter field.

Mr. Peck asks about the life of contact buttons on face plate rheostatic regulators. Ordinarily, currents of 10 to 20 amperes are carried although in large water wheel generators up to 50 amperes may be required. Life for small currents should be very long and for heavy currents a matter of several years. In this regard, the life of silver buttons of the regulator may be of interest. By the subdivision of voltage because of the great number of steps of resistance, the voltage per step is so low that practically unlimited life is obtained. Life tests of several millions of operations show no lessening of performance.

Mr. Angel raises some question about anticipating devices. The proper concept is that during any oscillation of a regulating system such devices shift the phase of response in such a manner as to reduce the oscillation. Anticipating devices do actually cause initiation of correction earlier that would be the case without them, and if unlimited control and other power were available in the system, it would be possible to prevent transient dips in the regulated quantity. However, because of limitations in control and other voltages, transient deviations do occur and the principal function of the anticipating device from a practical standpoint is anti-hunting.

Mr. Angel further asks about the accuracy of rod mill position regulators. Mr. Wright reports that 3 per cent deviations in speed may occur during transient disturbances.

H. H. ANGEL: On the steam unit you naturally have a slowing down in the output speed with quite an increase in load, and how quickly, or rather, with what accuracy will the motor speed follow the change in speed of the steam unit?

C. R. HANNA: This depends upon inertias, time delays, and other properties of the regulated system, and cannot be answered without study of the specific system.

Mr. Stoltz has asked that I duscuss the various factors that determine the selection of a regulator. The first important factor is the amount of current to be controlled. In the paper we have described the vibrating regulator, the direct acting rheostatic regulator, and the face plate rheostatic regulator which in the order named, have increasing current carrying capacity.

Another important factor is the required percentage accuracy. In this respect the electronic regulator excels because of its ability to respond to minute deviations without friction or magnetic hysteresis which are inherent to the electro-mechanical types of regulator. A particular example is the application of an electronic regulator for controlling voltage in one of our laboratories for the precise determination of lamp life. Voltage is controlled to within 0.1 per cent.

Where reliability is more important than accuracy, the mechanical, rather than electronic, type is ordinarily selected. Mechanical regulators have as low as plus or minus ½ per cent error which is usually small enough.

If still larger errors may be permitted, the rotating regulator is sometimes preferred. As pointed out in the paper, such regulators require an electrical reference voltage and it is sometimes difficult to obtain a sufficiently stable voltage for this purpose. Errors will be at least as large as the variations of the reference. In general the input to such regulators is higher than for the electronic or the electro-mechanical types. If this is not a disadvantage, the rotating regulator may be preferred.

The change in the regulated quantity with load or other disturbance is another factor which must be considered. If such deviations must be small, it is necessary to employ such stabilizing devices as the feed-back or damping transformer. These are smaller and more readily applied if the input requirement of the regulator is small. The vibrating and direct rheostatic regulators have particularly low power input requirements and therefore lend themselves readily to stabilization by the transformer method.

It may be seen from the foregoing that the requirements of a given regulator application when considered in conjunction with four or five regulator characteristics point pretty definitely to the type of regulator which should be selected.

Hardening of Inside Diameters by INDUCTIVE HEAT TREATMENT

By H. E. Somes, Chief Engineer

BUDD INDUCTION HEATING CO., INC.

DETROIT, MICHIGAN

Presented before the Pittsburgh District Section
A.I.S.E. February 24, 1941

▲ THERE are three vital things that a background obtained from the steel industry gives an engineer: a conception of the importance of sound engineering principles, of the necessity for large-scale production, and the desirability of obtaining trouble-free operations. These fundamentals, which were instilled in me at an early age, proved invaluable when I later became associated with the automobile industry.

My first experience with induction heating was in 1916, while I was working in a steel car plant. It had been suggested that electro-magnetic induction might be used to raise the temperature of steel plates for the purpose of working to remove the buckles in the plates after riveting. At that time, the application of high frequency generators to induction heat of any sort was unknown. Generators of the capacity and frequency we now use were practically undreamed of. We therefore used standard frequencies of 25 and 60 cycles, but it did not prove to be satisfactory. The apparatus required was too large, and the method too slow.

Later, I joined the Detroit Edison Company, with the assignment of developing new uses for electrical energy. The depression had struck, and new production methods which would lead to reduced cost and better quality were naturally much in demand. A number of proposals in this field were directed to the use of electro-magnetic induction for the drying of paint finishes and for the annealing of forgings and castings. In 1935 I engaged with the Budd Wheel Company to apply the electro-magnetic induction methods to heating baths and products for bonderizing and to the hardening of automobile hubs. The present method for the heat treatment of the inside diameters of cylindrical bodies resulted and was put to the task of hardening the internal bearing race of the rear hubs of Ford automobiles. The first practical application of the induction heating process to internal diameters was on this automotive part.

EARLY EFFORTS

The principle of heat treating by electrical induction is not new. As long ago as 1887, Colby had mastered the problem of heating by induction currents, as is evidenced by the patents granted to him in that year. Some believe that de Ferranti may have used the principle in the design of an electric furnace shortly before Colby received his patents. In any event, we may be sure that both of these pioneers would understand the principles at work in our more highly developed induction heat treating machine of today.

Other scientists, notably J. Kjellin and Frick, carried on the development of the method, and J. Kjellin's was probably the first practically useful induction furnace. It was first placed in operation in 1900. Later, Northrup made invaluable contributions to the art. His investigations, and the mass of data which he accumulated between about 1915 and his death in 1940, proved to be of importance to many who were seeking to perfect this new method of heat treating metals.

As the art of hardening progressed, a number of methods other than the induction method were applied with varying success, but while commercialized they were really make-shifts when compared with the shipshape induction method of today. One example was the treatment of an early automobile hub, in which it was attempted to harden the hub proper while the flange and stem were retained in a ductile state. This was imperfectly attained by means of a lead bath, the barrel being submerged in molten lead and then quenched at the bore. The method was used in many other applications, but engineers skilled in the art of metallurgy realized the difficulties attendent to the production of an ideal product in this way.

Many attempts were directed toward the production of a hardened inside diameter, while retaining the adjacent material in a ductile state. Experimental work

was done with the application of flame heating, and in some cases fairly successful results were achieved.

During my work with electricity I formed a number of ideas on the subject of cleaning and treating metals. A system was developed for the accelerated treatment of iron and steel parts in which we used electro-magnetic induction, and during the course of the early work we became interested in the problem of locally normalizing a portion of an auto hub. We used 60 cycle induction heating, and the operation proved successful. Several thousand hubs were so treated.

During this work, my colleagues and I had discussed many times the possibility of locally hardening the inside diameter of a hub to form a bearing race. From these discussions, the development stemmed.

Up to this time no successful method had been developed wherein the coördination of high speed heating and quenching had been successfully applied to the inside diameter of a product to be hardened. It was our aim to achieve a way to do this type of hardening. Numberless attempts had been made to solve the problem. We undertook to lick it.

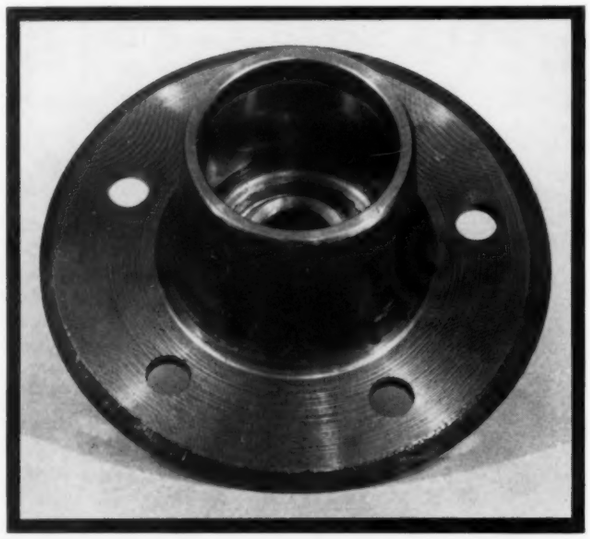


Figure 1—Automobile hub, the inside of which is hardened by induction heating, and which acts as outer race of roller bearing.

Our purpose was to develop a hard, wear-resisting bore on the inside diameter of a cylinder, while leaving the main body of the unit undisturbed. If this could be achieved, improved physicals would naturally result; for example, greater resistance to bursting or collapse would follow if this metallurgical condition—hardened inside diameter, with a tough, ductile main body—could be attained.

It was also hoped that a wider range of materials, including non-alloy steels as well as alloys, could be satisfactorily treated, thus making possible more durable, less costly, and more satisfactory designs.

All of these advantages have been realized. By means of the process, inside diameters are hardened to a predetermined depth, while the main body of the unit under treatment remains undisturbed. A control system which operates automatically insures uniformity of area treated, uniform depth of areas hardened, and uniformity of hardness throughout the treated area. Steady production of units of controlled metallurgical properties is thus assured.

The first application of the method was to a product in which it was required that a local area within an automobile hub be hardened so as to permit its operation as the outer race of a roller bearing (Figure 1). This particular product presented a number of problems.

You will notice that the body was irregular in shape, and consisted of a hub diameter to receive a roller bearing, a flange contiguous to this diameter for the mounting of the wheel and drum, and a tapered, bored stem to receive the axle. All boring and turning was to be done before hardening. It was necessary that the bearing diameter be hardened as near the bottom of this blind hole as possible. This requirement made the job most difficult, and it remains today, I think, the most difficult job we have ever done. It was a commercial success from the start, and today more than 4,000,000 of these hubs have been successfully treated without a single failure reported.

Months were spent in developing the automotive heat treating machines. No such machines for internal work had ever been built, and not even the necessary materials for many parts of the machines were available. We were planning to set up magnetic stresses the like of which had never before been known. Some of our problems may be of interest. One of the first requirements was to develop some sort of insulation that would take the heat successfully. The first insulation we used exploded like "popped corn" on its first "heat shock."

The heat "head" presented a most intricate problem in electrical and mechanical engineering. The head had to be developed for a machine, which, unlike most developmental apparatus, was to incorporate the refinements necessary for actual quantity production. It gave us many headaches! Not only had the head to be capable of performing the heating operation and stand up under it, but also it was necessary to develop a machine tool in which the sequence of operations—current application and application of the necessary water quench—could be performed automatically and in precisely timed relations with one another. In 1935–36 such a tool was built and operated, and a high frequency generator of capacity enough to operate it was installed.

The head was developed first. The only test that could be given was to insert it within the cylinder and apply the high frequency energy to determine if it would perform an effective job. We succeeded in this in 1935. In May, 1936, the machine tool had been completed and having a coördinated head which, our calculations indicated, would do the job on a fast time cycle, initial automatic production tests were made.

To our delight, a few hours after we began our experiments we had produced a beautifully hardened inside diameter on the first test pieces, while their main bodies, just as our calculations had predicted, remained in the original, ductile state. Only an engineer can fully appreciate the exhilaration which comes when, after months of planning, engineering, testing, and

"sweating blood" over a new development, a successful operation is achieved. It is for things like this that an engineer lives.

The first test period, however, was not without its tense moments. We had a lovable old mechanic who really got the most of the first test. He had been somewhat skeptical about the whole thing from the start, and he knew enough about electricity to know almost anything might happen when we turned the entire 300 kw. of our new generator into the coils of that little heating head, no bigger than a teacup. He made it perfectly clear that he didn't know what was going to happen, and if truth be told, I felt somewhat the same way myself.

The moment came, however. The contactor slammed home, the needles on our indicators swung upward—and then, right behind our skeptical mechanic, a short circuit occurred—it was on the contactor panel, as I recall—and it let loose like a six-inch gun. He jumped straight into the air, it seemed, at least three feet, and when he came down his legs were already working like the connecting rods of a steam locomotive. He didn't know where he was going, but he was going to get away from there. He did, too. A few moments later he came walking cautiously back from the railroad tracks outside the building, where he had finally halted, and sheepishly asked what had happened.

But the short cleared away and our machine soon proved successful in operation. Let us look at the typical result, the inductively hardened inside diameter. You will notice in Figure 2 how clearly the hardened area, which forms the bearing race, is demarked from the core of the piece. The process maintains the highest degree of accuracy and uniformity in area hardened, depth of the hardened area developed and hardness developed that I have ever observed. This is an unretouched photograph.

It is difficult for many to fully appreciate the sharp differentiation between the heated area—the shallow area which is hardened—and the core of the piece which, because of the speed of the heating and quenching operation, remains metallurgically undisturbed.

During 1936 some 10,000 pieces were processed. All went into production automobiles—many on road tests. Design work went forward on an automatic tool which could be put into the machine shop production line. It is interesting to note, however, that our first experimental machine took its place in and is still in operation in our production lines. After performing on approximately 200,000 automobile hubs it was temporarily retired to the morgue, but it was afterward resurrected and is now successfully performing a very difficult shell heating operation.

I don't think that in the first successes we fully realized the possibilities of this new method of hardening the inside surfaces of cylinders. There have been so many developments since then—so many new applications. I'm not certain that we fully realize the possibilities even today. Entirely new fields are opened in design and production engineering. But more of that later.

PRINCIPLE OF INDUCTION HEATING

At this time, it is probably in order to describe what happens when a section is treated by electro-magnetic induction. Briefly, all we know is, that if current, timing, and quenching are right, the section is hardened. That happens. Why it happens is another matter. We do know some of the things which lead up to its happening.

This differential hardening is accomplished through the concentration of high power, high frequency currents in the surface zone to be hardened. As applied in our method of treating inside diameters, the currents are caused to flow almost entirely in the shallow internal surface zone to be heated, and to be so concentrated that the temperature of the zone affected is raised to hardening temperature before any substantial amount of heat can drift to the core of the piece.

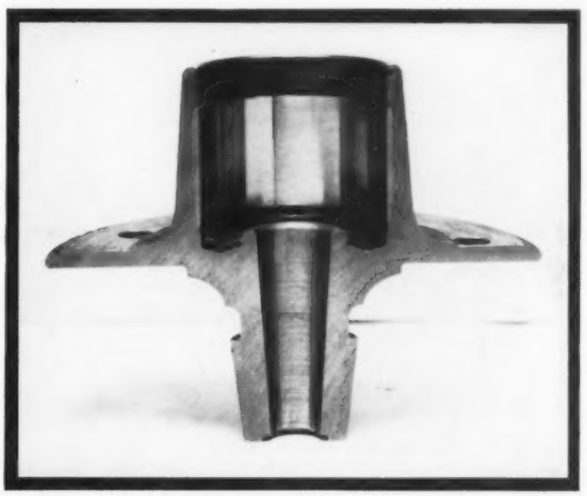


Figure 2—Sectional view of automobile hub, showing the inductively hardened area which forms the bearing race.

In this way, the required heat is almost instantaneously generated in the zone to be hardened. This thermal energy is then "trapped" through the immediate application of a controlled water quench. An extremely hard surface is thus obtained, while the core of the cylinder, due to the speed of the operation, has remained relatively cool and has therefore not been affected.

As the power input and timing of the current application, and the volume, pressure, and angle of direction of the water quench are accurately controlled, it follows that the hardness developed, the depth of the hardened area, and the area treated are also controlled within exceedingly close limits. The time required for the entire heating and quenching operation is a matter of but a few seconds.

THE MACHINE

The machine is a coördinated assembly of precision mechanisms. I don't want to go into too much detail, but a brief description of its component parts, source of

power, and controls, should prove of interest. These are as follows:

1. *Source of energy, metering equipment, conductors, etc.*

First, a source of high power, high frequency energy consisting usually of a motor-driven inductor alternator. The motor, of course, may be of either the induction or synchronous type, depending on the type of power available. It is usually mounted on a common base and directly connected through a flexible coupling to the inductor alternator. The generator shown in Figure 3 is installed at our Detroit plant, develops alternating current at 9600 cycles, and has a capacity of 500 kw. at 800 volts.

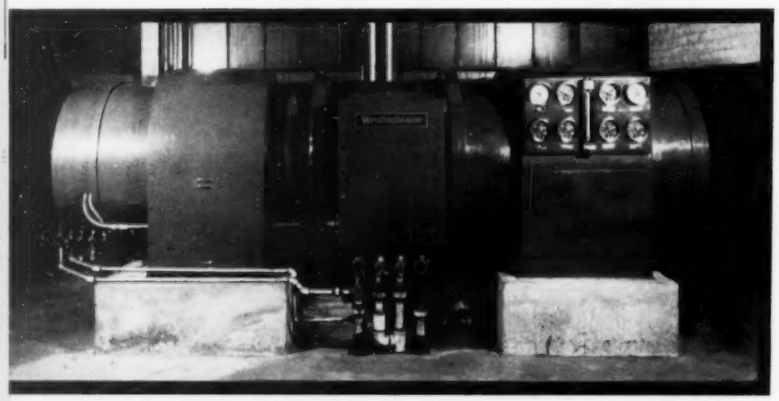


Figure 3—Hydrogen-cooled motor generator set for induction heating process, rated 500 kw., 800 volts, 9600 cycles.

Necessary exciters are furnished and may be driven on the common shaft or may be separately motor driven. The switching equipment for the high frequency power consists of a solenoid or air operated contactor.

Metering equipment consists of the necessary a-c. voltmeters, ammeters, power factor indicator, indicating watt meter and, in some cases, a variometer. The generator may be mounted in a position remote from the induction heating apparatus. The current is conducted from the generator panel to the heat treat machine usually by means of a two conductor lead sheathed concentric stranded cable. Such conductors reduce the reactance of the circuit, and with them we transmit this high frequency power over distances of from 500 to 600 ft. with a power loss in the order of only one or two per cent.

At the heat treat machine (Figure 4), the cable terminates in a suitable pot head and the connection is made to a sliding core switching transformer of special design. This transformer serves the dual purposes of (1) reducing the voltage to safe working voltage at the heat treat device and (2) accurately and safely switching this high power on and off the heat treat head. This is done through a vertical reciprocation of the transformer primary to remove it from inductive relation with the secondary during the off-load period, thus reducing current flow to the very small exciting current flowing through the primary windings. The load is applied by moving the primary into inductive relation with the secondary, causing current to flow through the work circuit.

A massive conducting arbor similar to the spindle of a machine tool connects the heat head with the transformer secondary. This conductor arbor is made of two concentric copper tubes electrically insulated from each other by means of a suitable insulating bushing placed between the inner and outer conductor tube. Connection is made between this conductor and a bank of tuning condensers by means of a similar concentric arbor. It may be noted that the transformer is placed at the top of the machine, the arbor and heat head being suspended from it.

A suitable work-holding fixture is provided (see Figure 5), and in this particular machine the work piece is simultaneously rotated and progressed axially in relation to the heat head during the heating and quenching cycle. In operation, it is necessary that the product be chucked so as to be held in precise relation with the heat head but not in contact with it. It will be observed that the arbor must be straight and in perfect alignment with the work holding fixture, since the work is rotated around the head and at the same time progressed axially of the head.

2. *The heat treat head and quench.*

The heat treat head, after all of the necessary motivation and sequences have been insured, is the vital part of the machine. This head consists of a tubular copper coil wound about a laminated iron core, all of which is mounted on a mandrel. This tube, being hollow, permits the circulation of coolant through the coil. Since these tubes are of small cross section, the orifice is perforce restricted and great care is taken that no obstruction to the passage of the coolant develops, since this is operated in some cases up to a current density of 200,000 amperes per sq. in.

The quenching device is placed directly below the heat head, being maintained in definite relation to it. For purposes of loading this machine, in which the quenching fixtures rise from below the head, the quenching device is retracted (*i. e.* lowered) from this relation during the loading and unloading period. This is accomplished by means of an air or hydraulic cylinder operating in timed and controlled relation to the other operations.

3. *The controller.*

The accuracy of the timing and control of the entire operation is vital.

All of the timed sequences are maintained by means of a sequencing controller consisting of a series of precision cam-operated switches. The drum on which the cams are mounted is arranged in this case to receive four sets of cams, the different sets controlling the operations for different sizes of cylinders to be heat treated. This controller is designed to give extremely high fidelity in timing of the controlled operations, and also to permit changeovers for treatment of different sizes of bores within a minimum amount of time.

The controlled movement of the work-holding fixture and the heat treat head is accomplished by a suitable motor-driven hydraulic system. The transformer primary, secondary and all connecting arbors are water-cooled. Cooling of the transformer coils is accomplished by passing a metered amount of coolant through both

the primary and secondary, the quantity being accurately controlled by means of several calibrated flow control switches. These switches automatically interrupt the control circuits on the transformer so that power cannot be applied to the heat head until the normal flow has been restored.

In order to avoid rust or corrosion, a great deal of stainless steel and bronze are used in the construction of the machines. Frames are carefully fabricated of steel and thoroughly painted.

Size of the machine is such that not more than 36 sq. ft. of floor space are required, which includes the necessary work room around the machine. Two such machines are set up and operated in our production line just as any boring mill may be set up and operated and the treated hubs are passed on right through to the inspection bench. No accumulation of stock is required for this operation, as we are able to heat treat the product, inspect, grind and hone as fast as the line produces.

Since the original machines and method, many new methods and machines have been developed. These permit the heat treatment of engine cylinders of many sizes, and tubes and pipe of longer lengths. Machine tools and fixtures to accommodate objects of many kinds and sizes have been developed.

4. *Operation of the machine.*

The setting of the machine for any given heat treating operation within its range is, as was noted above, quickly and easily accomplished by adjusting the controller and its cam-operated switches. Once this has been done, the correct heat head and work holding fixtures are in place and adjusted for the particular hollow object to be treated (cylinder, hub, tube, or what-not) the operation is quite simple.

Since the machine is fully automatic, the only requirement is that the operator place the piece to be hardened in the holding fixture. In the progressive type of machine, when this is done, the fixture closes and automatically elevates the work piece, (a cylinder, we'll say), to a position in which the heat treat head and the quenching fixture are brought into relation with the lower end of the cylinder. The cylinder is then progressed axially downward and rotated in relation to head and quench, the power is automatically applied with the quench following at the proper juncture to start hardening at the point desired, and the work is thereupon heated progressively and as progressively quenched.

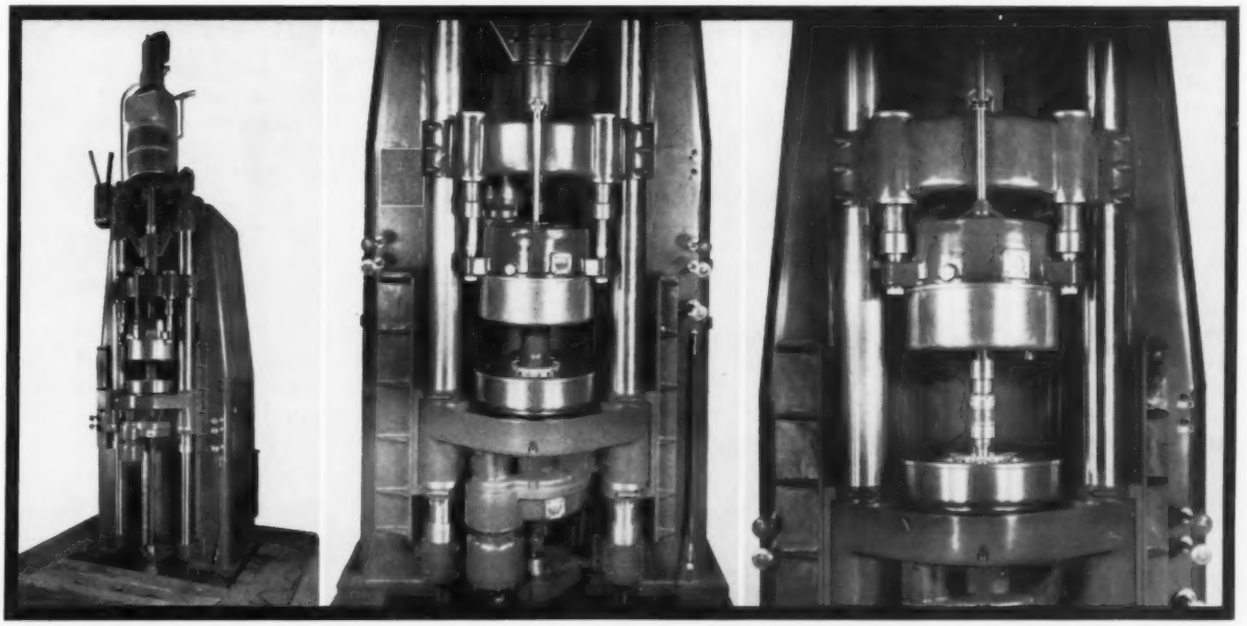


Figure 4—View of induction heat treating machine, showing transformer on top, with arbor and heat head suspended from it. *(left)*

Figure 5—View of work holding fixture and cylinder in place. The work is rotated and moved axially during heating and quenching. *(center)*

Figure 6—The quenching device is placed directly below the heat head, and is retracted by air or hydraulic cylinder during loading and unloading.

Both of these operations are very precisely controlled, the quench continuing until the necessary heat has been extracted from the cylinder. It is then shut off automatically and moves from its relation with the heat treat head, when the cylinder under treatment is removed.

This operation is reproduced periodically as indicated by the sequencing controller and the capacity of the machine.

SOME PRACTICAL ASPECTS OF THE PROCESS

We have recently made an installation in which inside diameters of cast iron liners are being hardened

to a depth of .070 in., and to a hardness of 52-55 Rockwell C. Liners from 10 to 15 in. in length, with bores varying from 3¾ to 5¾ in. inside diameter, are in production, all in the same machine. The machine is installed in the liner production line itself, where following the hardening operation the bores are honed to a final finish, and then the outside diameters are finish-turned for insertion into the cylinder blocks.

These finished sleeves are undoubtedly superior in physicals, wear-resistance and uniformity to any which have been previously produced.

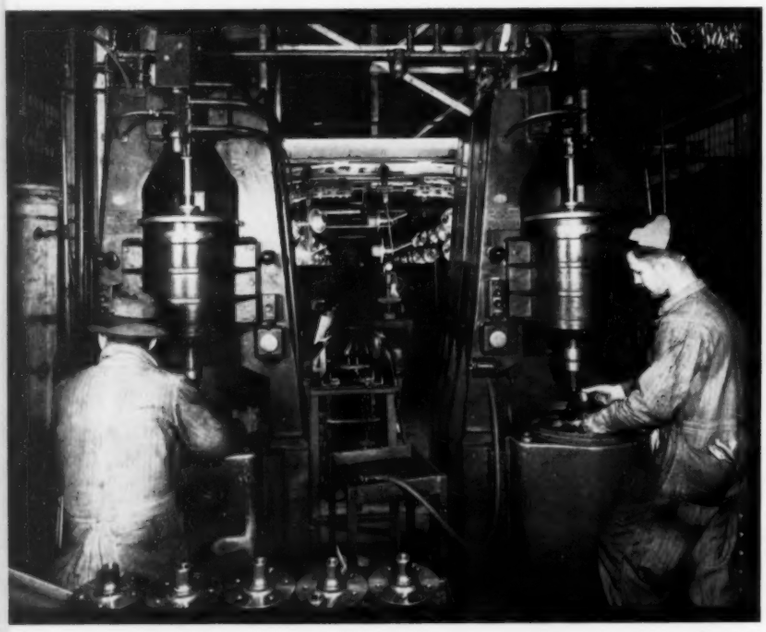
While the bores are extremely hard, providing maximum resistance to wear, the sleeves are not in the least brittle. Quality and uniformity of product are maintained to the highest standards.

The hardening of numerous other types of liners by the process has either been achieved or is under development. The method has proved successful in all applications attempted to date. Most of the cylinders treated have been poured from cupola cast iron.

A very interesting side-development in relation to the treating of cast iron cylinders is the use of the method as an additional inspection, as well as a method of hardening. It is observed that where the part under treatment is porous or cracked, an interruption to the heating current circuit within the piece takes place, evidencing itself by a melting of the surface or wall adjoining the defects, or, in the case of porosity evidencing itself by marked signs of overheating. Consequently, defective work pieces are easily identified. In fact, defects otherwise discernable only with magna-flux or microscopic inspection are easily checked, in this way, by the naked eye.

The heat treatment of the bore of a cast iron cylinder by induction is a simple and beautiful thing. Simple because you either unfailingly give it the correct hardening treatment, or you destroy it, and beautiful because cast iron becomes, in the zone treated, endowed with the wearing qualities of a fine steel. It is characteristic of the process that correct heating may be repeated endlessly. There is no compromise. With proper setting, perfect hardening must always result. This inspection phase is to a lesser degree applicable to the heat treatment of steel. Defects in steel cylinders, such as folds, splits, or massive inclusions which might otherwise pass visual inspection, will be uncovered during the application of this process.

Figure 7—View showing inductive treating machines used in production line.



APPLICATION TO STEEL CYLINDERS

Steel cylinders are hardened in substantially the same way, and at the same speed, as cast iron. Here, due to the higher homogeneity of the material, higher apparent hardness is obtained as measured by the Rockwell or Brinell method. We have successfully hardened steel to 69 Rockwell C, and in depths varying from .025 in. to ⅜ in., while some specially cast steels have been treated to a hardness of 78 Rockwell C.

SOME METALLURGICAL CONSIDERATIONS

When subjected to induction hardening, the metal under treatment is taken from the as-forged, as-cast state into the gamma or austenitic phase. On rapid quenching, certain changes take place: a fine grained martensitic structure is produced, the structure of the martensite being very much finer than as ordinarily produced by other methods. In many cases this has a characteristic pattern which is found only when the hardening is done by an ultra high speed process.

Because of the speed of the operation, there is no time for oxidation to occur, and only a slight discoloration is observed. The short time cycle inhibits objectionable grain growth, the precisely controlled quench also being a factor in this.

Distortion is held to a minimum because only a portion of the piece is heated to critical temperatures, while the adjacent part of the product remains undisturbed. This holds it to its original geometrical shape, as the main body or core retains full physical strength. Even in the case of cast iron, the distortion is of very small value.

Scaling, spawling, necessary straightening, cracking and grinding checks due to lack of uniformity of structure are no longer problems. Further, it has been found that annealing or normalizing treatments are less frequently required before hardening than when other methods of heat treatment are applied.

One of the advantageous properties of the hardened section of tubes inductively treated is that the hardened zone retains a fairly high degree of machinability, and we have experienced no trouble due to grinding cracks or drawing during the grinding operation.

In materials containing temper or uncombined carbon, recombinations of this carbon at a greatly acceler-

Figure 8—Cast iron cylinder, the bore of which is heat treated by the induction process.

ated rate can be accomplished, thus markedly increasing the hardenability and strength of the area treated.

The machine and process make possible the fabrication of improved wearing parts in nearly every type of machine in which bores of metal parts are subject to wear or stress. The material treated takes a beautiful finish on honing, and by means of the process we have been able to achieve a higher degree of hardness in a material of given analysis than with any other known method.

What we have developed is not only a process, but also a series of machine-tools for heat treating by induction, machines which reduce the new process of heat treating to machine-tool precision. Thus, the process is made to meet the demands of modern industry. Its operation is simple. The product is improved. Speed of production is increased, and perfect uniformity of the product is assured.

I am frequently asked how long a cylinder we can treat. The answer to that is, "How long a bore do you have in mind?" Machines we have already built handle lengths varying from a fraction of an inch up through several feet. Our existing designs contemplate unlimited lengths.

Many engineering departments of industry are at the present time considering applications of the process to their products, and these in many different fields. An interesting current application is to the hardening of oil well casings. It may safely be said that there is no field of industry in which it may not have extensive profitable application. Our new process and machines constitute the perfect complement to the well known process and machines for external hardening by electro-magnetic induction which have been available for several years, extending probably 100 per cent to the field of internal surface hardening, the art of hardening by the electro-magnetic induction which hitherto had been realizable only in connection with external hardening.

I think you will agree with me that our achievement represents one of those great forward steps which are the goal of all engineering practice: methods and machines which produce products of markedly superior qualities, and which are outstandingly adapted to high speed production requirements.

DISCUSSION

PRESENTED BY

C. C. LEVY, Industry Engineering Department, Metal Working Section, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania

E. I. POLLARD, *Design Engineer*, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania

E. H. HOLLENBACK, *Assistant Engineer of Tests*, Bethlehem Steel Company, Johnstown, Pennsylvania

H. E. SOMES, *Chief Engineer*, Budd Induction Heating Company, Inc., Detroit, Michigan

A. T. RUTTENCUTTER, *Industrial Heating Engineer*, West Penn Power Company, Pittsburgh, Pennsylvania

J. S. MURRAY, *Chief Electrical Engineer*, Follansbee Steel Corporation, Follansbee, West Virginia

WALKER ANDERSON, *Sales Engineer*, General Electric Company, Pittsburgh, Pennsylvania

G. E. STOLTZ, *Manager*, Metal Working Section, Industrial Engineering Department, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania

J. R. ADAMS, *Superintendent*, Special Products, The Midvale Steel Company, Philadelphia, Pennsylvania

WRAY DUDLEY, *Assistant Superintendent of Maintenance*, National Tube Company, McKeesport, Pennsylvania

P. H. BRACE, *Consulting Metallurgist*, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania

NEWELL HAMILTON, *Metallurgical Engineer*, Babcock and Wilcox Tube Company, Beaver Falls, Pennsylvania

M. R. McCONNELL, *Engineer*, West Penn Power Company, Pittsburgh, Pennsylvania

R. E. LOUDEN, *Electrical Engineer*, American Rolling Mill Company, Butler, Pennsylvania

C. S. BULLION, *Chief Engineer*, Socony-Vacuum Oil Company, McKees Rocks, Pennsylvania

S. L. GOODALE, *Professor of Metallurgy*, University of Pittsburgh, Pittsburgh, Pennsylvania

C. C. LEVY: The high frequency inductor generator differs from the conventional pole excited type in two important features. The first is the absence of windings on the rotor. The second is the arrangement of the magnetic circuit and the exciting coil. In the typical inductor generator for high frequency, the frame consists of two cylindrical rolled steel rings, one of which fits over the other. The field coil is also cylindrical in shape; it is slipped over the outer frame, and fits in a recess in the inner frame. Flux is forced to take a particular path by non-magnetic spacers between the two sections of the frame.

The water cooling coils, which are actually straight pipes inserted in the stator iron and connected by short pieces at the ends, are above the single armature coil

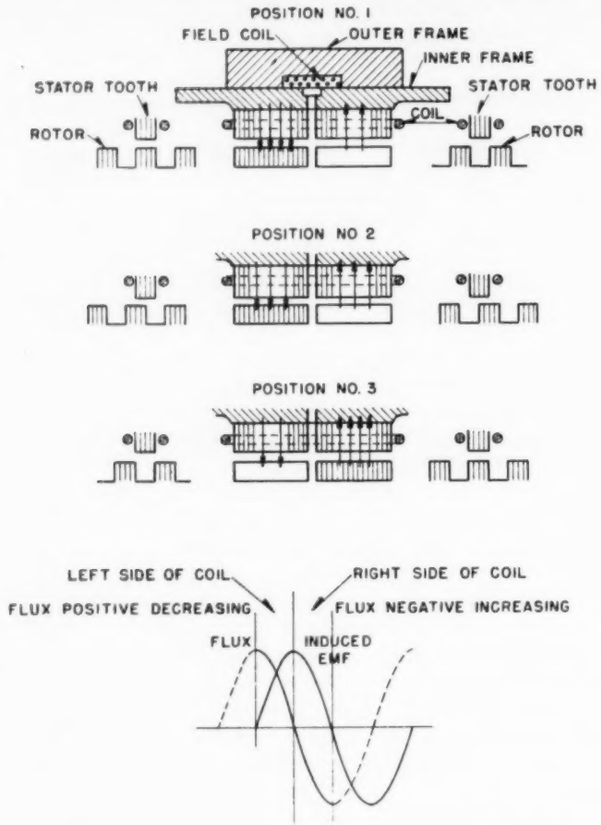
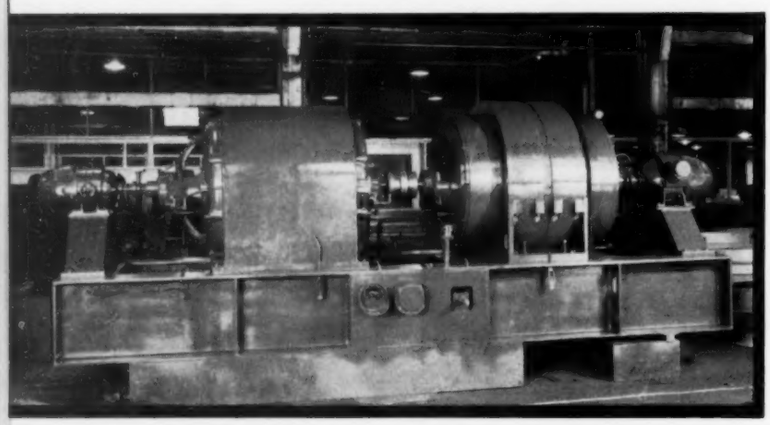


Figure 1—Variation of flux and induced emf. in armature coil of high-frequency inductor generator.

which surrounds each stator tooth. The rotor punchings are fastened to a solid forged steel shaft of considerable diameter.

The rotor of the high frequency inductor generator is of two-part construction, with an unusual arrangement of the teeth in one part lining up with the slots in the other part of the rotor. The reason for this construction will appear later. In the stator, also of two-part construction, the slots in each section run straight through, and are not staggered as in the rotor. The sides of the armature coil fit in adjacent slots.



The total exciting flux is constant in these machines and it is not obvious at the first glance how the alternating emf. is obtained. Figure 1 shows graphically the flux conditions in the air gap as the rotor revolves.

Consider first, the left hand portion only of this sketch. In position 1 it is clear that the air gap reluctance is a minimum, since a stator tooth is just above a rotor tooth. The air gap flux will therefore be a maximum at this moment. As the rotor advances in the direction shown the air gap reluctance increases, and the air gap flux correspondingly decreases until it reaches a minimum value at the point where the stator tooth is over a rotor slot. An emf. is induced in a portion of the armature coil linked with this flux. Now turning to the right-hand side, if we had exactly the same arrangement of rotor teeth and slots on this side as we have on the left-hand side, it is clear that the emf. induced in the left-hand side would be exactly opposite to the emf. in the right-hand side, and the net result as far as the complete armature coil is concerned would be zero. We could, of course, avoid this by having two independent armature coils, one surrounding the tooth on the left, and the other the tooth on the right. The two coils could then be connected so as to reverse the polarity of the right hand side and make the emf. add. A simpler way is to design the rotor so that the right hand will have a slot lining up with tooth on the left-hand side. With this arrangement of the rotor a single armature coil can be used, and the emf. in one-half of the coil will add to the emf. in the other half. We can now understand the reason for the special arrangement of slots and teeth in the rotor. The frequency of these machines is determined by the usual formula, frequency $= \frac{\text{rpm.}}{60} \times$ number of rotor teeth or poles.

Figure 2 illustrates a 600 kw., 100 per cent power factor, 3000 cycle motor generator set which has been designed as an enclosed self ventilated unit. The enclosing covers are omitted in this view. The motor, a 4-pole synchronous machine, is at the left of the illustration and the high frequency generator at the right. Two totally enclosed directly connected exciters at each end of the set provide excitation for the motor and the generator. Ventilating air for the motor is drawn from each end of the motor shaft and discharges through air coolers which are mounted below in the bedplate of the set.

The air for the generator is drawn from left-hand end through the air gap and discharged through the cooler in the bedplate at the other end. One noticeable result of the enclosure is the marked decrease in the noise which is a pronounced characteristic of the open type high frequency generator.

In most industrial plants it is necessary that the open type motor generator set be furnished with clean ventilating air. When the cost of cleaning as well as supplying this ventilating air is considered, the use of totally

Figure 2—View showing 600 kva., 100 per cent power factor, 800 volt, 3000 cycle motor generator set without enclosure.

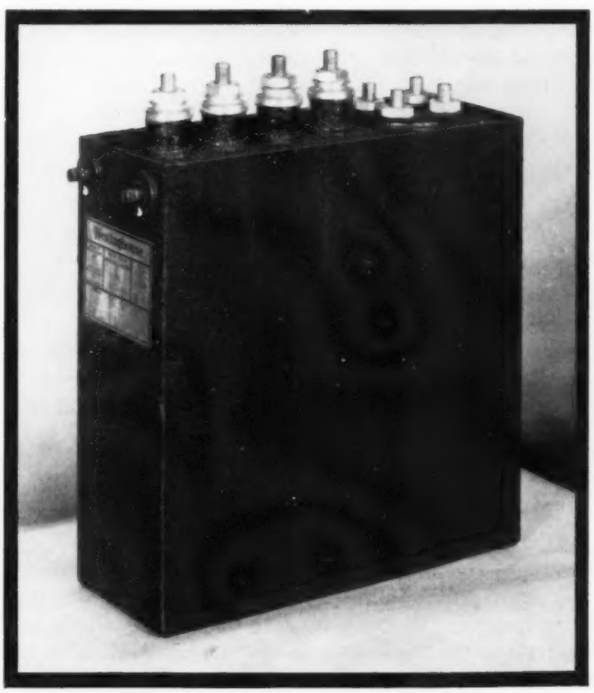
enclosed self ventilated units such as this, presents many advantages.

When frequencies of the order of 10,000 cycles are required it is necessary to use 3600 rpm. speed because stress limitations preclude the use of the larger diameters required at lower speeds.

When in addition the capacity required at this frequency is 500 kw. or more, the friction and windage losses of the 3600 rpm. air cooled design become quite large and its efficiency is adversely affected. Our engineers proposed the use of hydrogen cooled motor generator sets to meet this situation, and designed the first 9600 cycle hydrogen cooled motor generator set to be used for induction heating load. This unit, illustrated in the paper, has been in successful operation for the past year. The motor is on the left-hand side of the illustration, the generator on the right-hand side. The design is so uniform that it is difficult to distinguish the motor from the generator. This is a good example of what can be accomplished when a motor generator set is designed as a unit, and not as a motor coupled to a generator. If this unit had been of the conventional air and water cooled design, it would have been considerably larger and its efficiency considerably less. The hydrogen cooled motor generator set represents at present the most advanced type of design for furnishing energy to induction heating and melting loads of large capacity and high frequency.

The induction melting furnace operates at a very low power factor. Induction heating loads are better, but their power factor is still low. It is obviously uneconomical to design generators to supply the total kva. of such loads, and capacitors are as essential as the power supply. The leading kva. supplied should be

Figure 3—Water cooled capacitor for induction heating service.



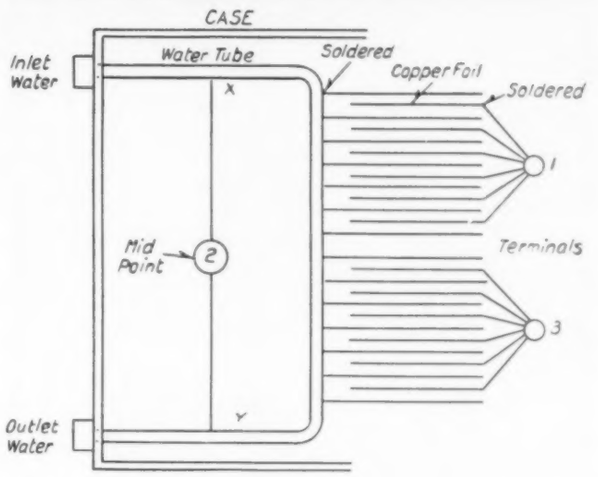


Figure 4—Schematic arrangement of interior of water cooled capacitor.

sufficient to balance the lagging kva. of the load, so that the generator can operate as close to unity power factor as possible. The number of units will then depend on the permissible kva. rating of the unit.

A 60 cycle air cooled capacitor is an assembly of metal foil conductors separated by specially treated paper dielectric. The assembly is impregnated and vacuum treated, and placed in a case which is filled with a non-inflammable insulating liquid and provided with suitable terminals. A capacitor of this type will have a kva. rating which is determined by the permissible voltage stress on the insulation and the ability of the case to dissipate the losses by natural radiation.

Now if we hold the voltage stress constant but increase the frequency, the kva. drawn from the line increases in direct proportion but the losses also increase in almost the same proportion. By dissipating the losses due to increased frequency through efficient water cooling it is possible to operate capacitors on high frequency at a very much increased kva. rating. For example a 230 kva., 9600 cycle unit with internal water cooling is the same in size as a 15 kva. air cooled 60 cycle unit.

There are two major problems in the water cooled designs: (1) the large amount of heat to be transferred from the working dielectric to the water cooling coils; (2) the large currents generally required. The first problem makes it necessary to design an efficient cooling system which removes the heat at its source in the working dielectric. The second problem is particularly troublesome at low voltages and high frequencies, because the heating of the case at the higher frequencies due to currents flowing in the terminals, and even in the water cooling coils themselves, require special design and special material to avoid serious limitation to the rating of the unit.

Figure 3 shows a standard 4 terminal water cooled unit used very frequently in induction heating applications. The short time "load on" characteristics of many induction heating applications makes it desirable to have these multi-tap units. The unit shown can be

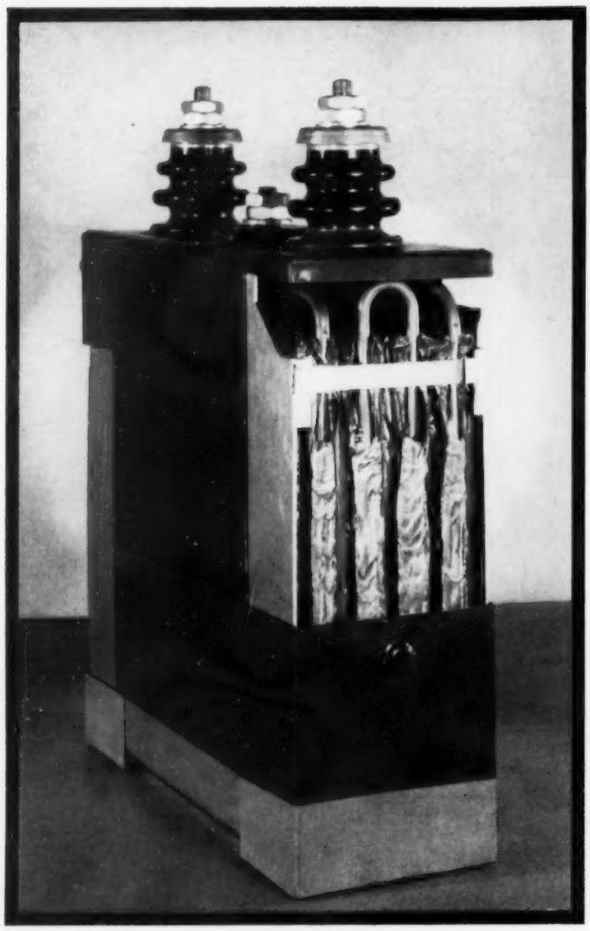
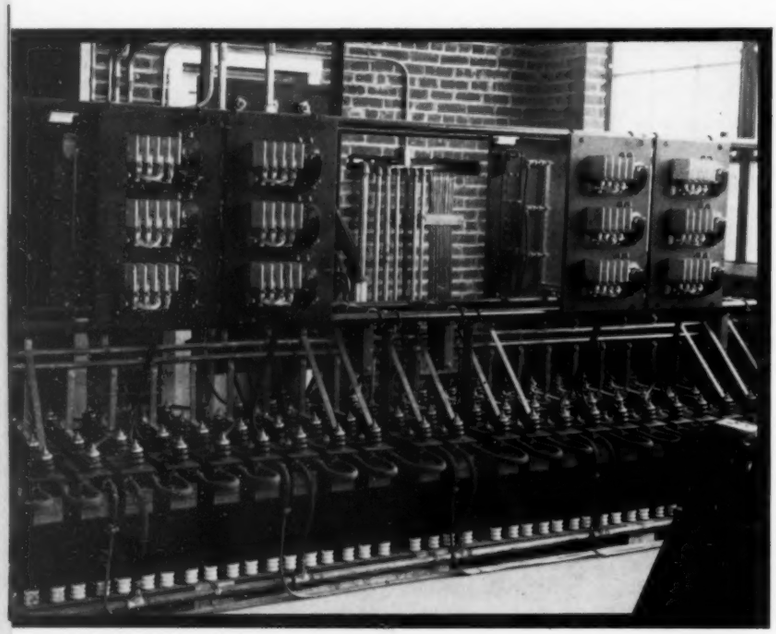


Figure 5—Cutaway view of water cooled capacitor assembly.

Figure 6—Installation of water cooled capacitors for induction melting furnace.



used for (1) 300 kva. at 200 volts and 9600 cycles on a 10 per cent duty cycle; (2) for 120 kva. at 200 volts and 9600 cycles but with a duty cycle of 65 per cent; (3) for 230 kva. at 315 volts, 9600 cycles and 100 per cent duty cycle. These widely different ratings on the same unit indicate the fact that current is a very definite limitation to the rating and the drop in current by stepping from 200 to 315 volts makes a very decided difference in the kva. rating and the duty cycle of the unit.

Figure 4 shows in schematic form the internal arrangement of a water cooled capacitor. There are two separate sections shown. The horizontal lines represent the copper foil conductors and the working dielectric lies between them. The copper foil of each polarity is extended beyond the paper dielectric, on each side, one set of these extensions being bonded together and attached to a flexible lead while the other set is securely bonded to the cooling pipe and connected to the ground stud terminal. The cooling coil consists of a continuous length free from sharp turns, and wound so that it forms a non-inductive path for the currents that flow in it. This is an extremely important point in limiting the temperature rise due to eddy currents in the case.

The two long ends are bent over at 90 degrees and form the incoming and outgoing outlets on the side of the case.

Figure 5 shows a cutaway view of the complete assembly in which the manner of bonding the foil to the pipe is clearly shown. The effectiveness of the solder bond between the foils is illustrated by the fact that the temperature of individual foils at the water end will vary over a range of 30 degrees before solder bonding and are held within 5 degrees of the water temperature after soldering as shown.

Figure 6 shows a commercial installation for an induction furnace application. The contactors shown are used to change the value of connected capacity as required in the operation of the furnace.

It is impossible within the scope of this brief discussion to cover many interesting features of design which have been worked out to obtain a kva. rating on these units which will be economical for the user of induction heating equipment.

E. I. POLLARD: I would like to compliment Mr. Somes and Mr. Levy for the very fine papers presented. Mr. Somes' paper reveals that he is truly a pioneer in the field of high frequency inductive hardening.

Regarding Mr. Levy's discussion of the motor-generator sets, it should be emphasized that these high frequency generators are built for industrial service. The principal thing we have to guard against is the problem of unbalanced magnetic pull between rotor and stator when the rotor is not magnetically centered in the stator. In the interest of economical generator design, it is essential that short air gaps be used. When the rotor is displaced from a central position in the stator by as little as 10 per cent of the air gap length, the unbalanced magnetic pull is almost as much as the weight of the rotor. Consequently, the design of the bearings is made quite liberal so that they will safely carry not only the weight of the rotor but additional loading due to the unbalanced magnetic pull. The air gap alignment is carefully adjusted at the factory before

shipment. It is also necessary to check the gap alignment after installation before the generator is placed in service.

Mr. Levy also discussed the problem of cooling high frequency generators. Water cooling applied by means of transverse pipes through the stator core laminations has been used on our inductor type generators for about 15 years. The arrangement of parts in an inductor generator is ideal for the use of water cooling, which permits placing the cooling medium in intimate contact with those parts in which the heat is generated. This results in a smaller generator for a given rating, and eliminates the necessity of vent ducts which might become clogged up with dirt. Another advantage is that less ventilating air is required for the motor generator set. The absence of ventilating air ducts in the core, and the reduced air volume required result in a less noisy machine.

At present our small generators are air cooled. The larger machines employ water cooling combined with air, the air being blown through the air gap from one end of the machine to the other, to cool the rotor. It is not necessary to take unusual precautions in order to obtain a clean air supply as far as the generator is concerned, which from this standpoint is comparable to an open type squirrel cage induction motor of the same size.

A 500 kw., 9600 cycle motor generator set using hydrogen instead of air as a cooling medium has been in operation about six months. The design of this set was undertaken on an experimental basis, and many novel features have been incorporated. Our factory tests and subsequent operating experience have shown that this set is completely successful and exceeds our expectations in several respects. For instance, it is unusually quiet in operation. A second set of this type is now being built. Our conclusions are that hydrogen cooling is ideal for large 3600 rpm. generators at the higher frequencies of 9600 cycles and above.

E. H. HOLLENBACK: As you all doubtless know, steel can be classified into deep or shallow hardening types. I am interested in knowing whether time cycles for heating and quenching must be modified when handling deep as against shallow hardening steel or whether a standard operation can be set up without knowing the type of steel used.

H. E. SOMES: I have found slight differences of behavior between a shallow hardening steel and a deep hardening steel of say SAE. 3345 wherein the total depth of hardened case might vary .010 in. to .020 in. with a standard heating cycle between one of these steels and another. Where such small change in the depth of case is not objectionable no change would be made in the cycling or time or heating rate. Possibly a change would be indicated in the rate of quench. Where a case depth greater than $\frac{1}{8}$ in. is required the rate of heating and the cycle of heating and quenching may be modified to some advantage.

A. T. RUTTENCUTTER: Mr. Somes emphasized the very close clearance demanded by this heating method, which transfers high frequency electrical energy magnetically to the inside diameters of the product. Only rigid machine tool design will provide both free movements and adequate power input for rapid precise heat treatment.

The present induction type generator design described by Mr. Levy, interested me considerably as it follows closely the original 10,000-cycle induction design of Mr. Lamme, on which I ran shop tests several years ago. Some strange phenomena developed at this frequency; for instance, an iron vane type volt meter indicated about the same deflection on the low scale as on the high scale. Therefore, we had to find special means to measure 10,000-cycle currents. The rotating part construction was nickel steel with 400 polar projections which at 3000 rpm. or 10,000 cycles, created a most disturbing high screech or whine. This side light will explain that inductive heating has had an interesting background extending to the present day of push-button controlled power plants, that can supply different frequencies according to the needs of the job.

J. S. MURRAY: In connection with the reference to laminations, how thin are the sheets?

E. I. POLLARD: We use the best grade of standard electrical sheets we have available, which are 14 mils thick. Several years ago, about 1928, we built several machines using 5 mil thick silicon steel. At that time we found that the thin sheets offered insufficient advantage over the standard thickness to justify the additional expense. The lower "stack factor" of the thin sheets results in a higher magnetic flux density in the sheet itself, which almost compensates for the lower unit loss in the thin material for the same density.

WALKER ANDERSON: I heard ratings mentioned of 300 to 500 kilowatts, and pieces 30 ft. long. If you should tackle such things as oil well pipe, and assuming that it would have to get the same speed of heating, would the kilowatts go up in proportion to the length of the piece; or how do you handle a long piece?

H. E. SOMES: In the treatment of oil well piping on tubes of similar dimension wherein the length is long in proportion to the diameter, we use a progressive method of heat treatment in which a heat treating tool and quench are drawn progressively through the bore. The requirements of this type of tooling are in the order of 100 kw. capacity for each inch of diameter of the bore. Therefore, where a tube is of 8 or 9 in., a generator of somewhere between 600 and 900 kw. would be required.

WALKER ANDERSON: Does length increase the wattage?

H. E. SOMES: No, the length does not increase the wattage where the job is done progressively, except where extremely high rates of production are involved. Normally with a heat treat head, the effective part of which is 2 in. long and which travels in relation to the work piece at the rate of 1 to 2 in. per sec., the power requirements are of the order just given. Where, however, more than several inches must be heated per second, larger apparatus will be required.

WALKER ANDERSON: I think that answers my question. In effect, this means that for pieces of any length beyond a few inches, you heat progressively, and

a head, carrying up to around 900 kw. maximum and around 2 in. in length, moves from end to end of the piece with the quench following close behind.

G. E. STOLTZ: How is the frequency selected? Is it chosen on the basis of the depth to be treated?

H. E. SOMES: The frequency of 3000 cycles was originally selected because through its use hardened case depths of from .060 to .120 in. could be quite readily achieved in the size bore that we were interested in, namely 2.8 in. It was also selected because it was at the time the top frequency that the electrical manufacturers would undertake to build into a machine the size that we required. That it was a wise choice and one at which an optimum relation between cost of equipment and performance was had, has been demonstrated widely. However, where higher rates of heating to obtain somewhat shallower depths of hardening is required, higher frequencies at greater capacities are indicated; therefore, that is the reason why the 9600 cycle hydrogen cooled motor generator set described by Mr. Levy was built. You are all well acquainted with the net effect of increasing the speed of rotation on a motor or internal combustion engine and its ability to deliver more power. By increasing the frequency within practical limits, our heat treat heads will deliver more power into the work piece, thus reducing the amount of heat which may drift away from the heated zone and also affecting the so-called skin depth to which heat will be generated.

MEMBER: Is rotation of the work piece always used; and what happens when not rotating?

H. E. SOMES: Where uniformity of hardening is required, we always rotate either the work piece or the heat quenching device. In general, we rotate the work piece. This is made necessary because of variations of flux distribution due to the starting and finishing of the induction coil and the necessity for bringing the leads into and away from the coil. Also, and importantly, it is necessary in order to compensate for irregularities in the discharge of the coolant through the quench devices. Irregularities of quench can very seriously effect the hardening of materials of low hardenability and by rotating the piece in relation to the quench these variations, unless they are of a larger nature, can be accommodated.

J. R. ADAMS: With respect to hardening, I remember in 1921 we put in an induction melting furnace, which I had the job of making run. During our experiments we noticed that we heated the exterior while the interior remained unheated for a considerable length of time. That led us to believe that this method of heating might be applied to surface hardening. We experimented with tools and small rolls, and were more or less convinced that this method of heating had some possibilities.

I should say that we have now reached the point where we are hardening cylinders by inductive heating, 12½ in. in diameter by 42 in. long. I am speaking of hardened steel rolls. This method of heating has many things to commend it. It is possible to set up a time table to heat and harden that way. You do not really need to consider temperatures or anything else after you once set your conditions on a certain schedule. For small diameter rolls, this method of heating has much to commend it.

I was interested in a statement made a few moments ago about rotating when attached to the coil. That is true provided the velocity of your piece through the coil is high, say four inches per minute, which is much slower than anything I heard discussed here Where you want definite hardening, that is quite satisfactory and it is not necessary to rotate the piece that passes through split inductor. However, the inductor is not adapted for the greatest depth of hardening and we find, with coils of a set design in length, that release gaps can be applied advantageously to the method of induction heating for hardening cylinders. Of course the cylinders have a relatively thick wall and you would have to set your time and your power very accurately for any given depth, but it can be done and it is a very advantageous method of heating in that the control is very exact.

I have heard this method of heating discussed on several occasions and have heard it said that this method of heating does something mysterious to the steel. With that we do not coincide. You get extremely fine structure if you heat this enough, but you can also get that if you heat by other means. There is nothing to the theory that inductive heating produces something mysterious. It is simply a very exact tool by which you can harden and control far better in small sizes than by the ordinary methods of hardening.

WRAY DUDLEY: While Mr. Somes' methods of heat treating interior surface areas appear quite simple and easy from his description, it is quite evident he has had to work out many difficult problems. I have had some experience with induction heating of tubular products, using frequencies of 25, 60 and 175 cycles, and encountered many difficulties in providing suitable induction elements to meet the requirements of each application satisfactorily. No doubt Mr. Somes also met plenty of grief before he achieved the present success.

I would like to submit a few questions: In treating the hub, is the heat applied progressively?

H. E. SOMES: The hub is treated by the "one-shot" process. In other words, the heat head is inserted into the bore and is so designed as to introduce the heat into the exact area in which hardening is required. After the final heating, which takes 1.8 sec., a very accurate quenching device is inserted as soon as the heat is withdrawn and the coolant is accurately introduced into the bore of the hub. The progressive method is not practical in the treatment of products such as this hub where one end is blind and it is not possible to run the coil or the heat head through the bore.

WRAY DUDLEY: Is quenching done in the same elapsed time as the heating?

H. E. SOMES: No, the quenching requires more time than the heating. For instance 1.8 sec. is used to heat and approximately .15 sec. is required to withdraw the heat head and introduce the quenching device. The water is applied as soon as the quench head is introduced and the quench takes 6 sec. to complete.

WRAY DUDLEY: What is the clearance between the inductor coil and the inside diameter of the tube?

H. E. SOMES: .020 to .060 in. is commonly used on precision machine parts. Larger tolerances can be used in bores from 4 in. upward where required, at a slight reduction of efficiency.

WRAY DUDLEY: Is this inner diameter of the hub used for anti-friction bearings?

H. E. SOMES: Yes.

WRAY DUDLEY: Does it require grinding?

H. E. SOMES: Yes, grinding is performed after hardening after which the part is honed. This grinding is not necessary because of distortion but rather in the manufacturing process it is more practical to open up the production tolerances on concentricity and size of bore and correct by grinding out .003 to .004 in. than to attempt to hold it by a turning and boring operation. Also, to those of you who are acquainted with honing requirements, even with a fine feed on your boring tool, you would have to remove .005 to .008 in. on the diameter in order to remove the tool marks. To remove this amount of hardened stock by honing would be impractical.

WRAY DUDLEY: Mention was made of the necessity of holding close air gaps in the high frequency generators. About what air gap exists and what variation of air gap is permissible in the 600 kw. generator?

E. I. POLLARD: The air gap is approximately .052 in.; on a 9600 cycle machine .070 in.

WRAY DUDLEY: How much variation in radial gap is permissible?

E. I. POLLARD: Five per cent.

J. R. ADAMS: One question has interested us somewhat in the hardening of cylinders, particularly thick wall cylinders. We have observed when heating that as the piece heats up and approaches what we assume is the critical, that there will be dark and light bands on the cylinder. Does that mean we are getting a non-uniform density of flux, or is it due to a change in the composition of the iron oxide on the surface at that temperature? We have not been able to observe any difference in the structure of the metal. I am wondering whether someone present can throw any light on the subject.

H. E. SOMES: You are speaking about heating the outside diameter of a cylinder?

J. R. ADAMS: Yes.

H. E. SOMES: From previous experience, it would be my judgment that the light and dark bands described by Mr. Adams are caused by non-uniform distribution of the flux. We have made a number of studies of such lack of uniformity. As I stated earlier, the heating may be improved by rotating the piece. Of course, the importance of perfect heating is much greater as the speed of heating increases since there is no time to level out temperature variations through conduction.

P. H. BRACE: Mr. Somes is to be congratulated on the success of his work which must stand as a remarkable achievement in precise coördination and intensive application of such diverse, even antagonistic, agencies as electricity, high temperature and water. It is a great stride in the present day march of mechanization in the field of heat-treatment of metals.

Mr. Somes mentioned the possibility of machining of his induction hardened steel when Rockwell C hardness was as high as 65. I am somewhat surprised that this achievement is accepted with such equanimity by an audience of steel people.

H. E. SOMES: I said there were tricks to the machining of this hardened material but neglected to say that there is quite a bit of a trick involved. We have some samples tested to 65 Rockwell C which recently hardened to a depth of .3 in. and in which we machined 16 holes 7/16 in. in diameter and held them true to within the tolerance of .001 in. Due to the contour of the piece—we had a corrugated hardened structure—we had to machine the piece after hardening. There are certain products in which holes have to be put in after the piece is hardened since untoward stresses or minute cracking may take place particularly around the circumference of the hole if the holes are machined in before hardening. By hardening the bore first and machining the holes in afterward, we are able to assure satisfactory performance.

NEWELL HAMILTON: There undoubtedly must be some applications of this process in products that could not possibly be rotated such as a rather large vessel containing an opening, the bore of which is to be hardened. I should like to ask Mr. Somes if he has ever considered or had experience with such a problem, and what is involved in the rotation of the hardening head as compared to the rotation of the stock which is being hardened.

H. E. SOMES: We have a machine in Detroit designed and built to permit the rotation of head and quench while the work piece is left stationary. The quench becomes a little more difficult since we lack the centrifugal force which is present between the coolant and the cylinder while the cylinder is being rotated and which keeps the coolant in a wiping contact at the time of quench. However, where we have had to use this principal, we have been able to work out the problem satisfactorily.

M. R. MCCONNELL: How small an object in diameter can you handle, and how large? Also, I would like to ask if you have heated tubes, or similar objects for upsetting, by this method.

H. E. SOMES: Tubes of an internal diameter of 2 in. and upward are readily heat treatable by this method. Where the material is of sufficient value, that is to say where the cost of heat treatment can be justified, smaller diameters than 2 in. and lengths of say 30 and 40 diameters can be accommodated down to 1½ in. Factors such as wall thickness and the like will, of course, have to be considered. Short hollow cylinders of less than 1½ in. inside diameter may be accommo-

(*Please turn to page 58.*)

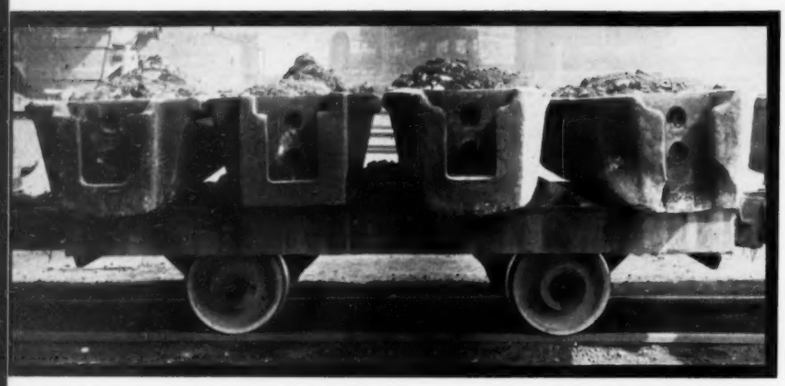


Figure 1—Welded charging boxes offer the advantages of light weight and low initial cost.

WELDED

▲ THE purpose of this paper is to present in a simple manner the welding practice as developed at our Steelton open hearth department during the last three years. In every case, the applications of welding herein described have proved satisfactory and economical.

In order to follow some system in describing the different applications of welding I shall start in the scrap yard and follow through the open hearth.

In the scrap yard the charging buggies are of all welded construction. These were built a number of years ago, before shielded arc electrodes were in common use. In spite of the fact they were welded entirely with bare wire, they are still in very good condition.

WELDED CHARGING BOXES

Between the years 1928 and 1938 the open hearth department purchased from the steel foundry an average of one hundred charging boxes per year, with an average weight of 2200 lb.

In an effort to reduce this item of expense a design was drawn up for an all welded charging box, fabricated entirely from rolled steel, including the head.

During January, 1938, four experimental boxes were made following this design. The main body of the box consisted of a $\frac{5}{8}$ in. plate, the head end $2\frac{1}{2}$ in. plate, and the other end $\frac{7}{8}$ in. plate. A 1 in. x 2 in. stiffener bar was welded around the top of the box. These boxes weighed 1500 lb. each. They were put into service and after three months were inspected and it was decided to make a group of 50 boxes.

In order to get comparative results, these 50 boxes were divided into two groups of 25 boxes each. One group was fabricated with cast steel heads and the other group with fabricated heads, using rolled steel. Two kinds of electrodes were used on each group and one-half of the boxes with each type of head were stress relieved at 1200 degrees F. The other half was put into service in the "as welded" condition.

With fifty boxes to make we could justify the cost of a set of dies for forming the body of the box. These dies were fabricated from rolled plate and welded at a considerable saving over the cost of cast iron or steel dies. The total cost of the dies complete, including all machine work, was $7\frac{3}{4}$ cents per lb.

These 50 boxes were completed and put into service during June and July of 1938. After these boxes were in service for about eight months the following conclusions were drawn:

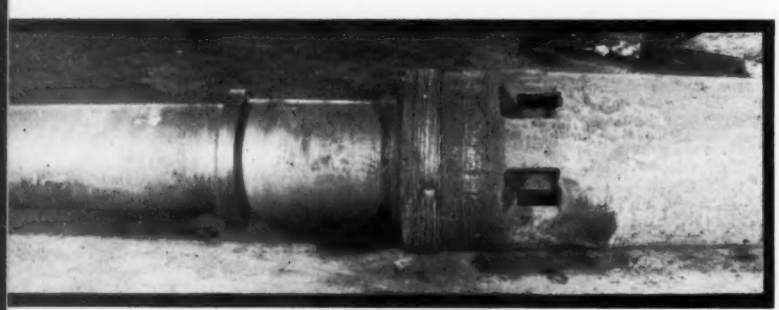
1. Cast steel heads should be used on all future boxes.
2. Stress relief is not necessary in this case.
3. All welding on the head end of the box should be done with carbon-molybdenum .50 electrodes.

The material required for one box is as follows:

Cast steel head—435 lb.
Main plate 54 in. x 7 ft. 5 in. x $\frac{5}{8}$ in.—860 lb.
End plate—104 lb.
Stiffener bars 17 ft. 0 in., 2 in. x 1 in. bar.
Electrodes—38 lb.
Total—1557 lb.

The preparation of material and assembly of the boxes are extremely simple. The cast steel heads are ready for use as they are received from the steel foundry. Stiffener bars are ordered cut to the proper length. The body of the box is a 54 in. wide universal plate and is ordered cut to the proper length. The light end of the box is burned from 20 in. universal plate, using a travelagraph equipped with two torches. This burning and the bending of the main plate is the only work done in the shop to prepare the material for

Figure 2—Welding the ram directly to the charging machine peel eliminates the use of the large taper keys formerly used.



AUXILIARIES

By C. C. Keyser, Welding Supervisor

BETHLEHEM STEEL COMPANY

STEELTON, PENNA.

assembly. The forming of the main plate is done cold, using a hydraulic press.

The boxes are assembled and then put on a one ton capacity welding manipulator for welding. A templet is used to mark the location of the drain holes in the bottom of the box and these holes are then used for bolting the box to the face plate of the manipulator. The head is welded into the box with carbon-molybdenum .50 electrodes and all other welding is done with a standard down-hand type electrode. The stiffener bars are welded top and bottom with a single pass using 5/16 in. diameter electrodes. All other welds are made with 1/4 in. diameter electrodes.

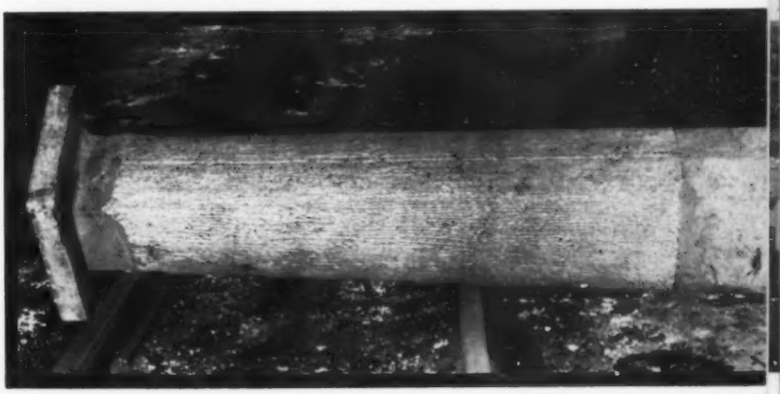
The welding manipulator used in welding the boxes is responsible for a direct saving of six hours welding time per box. This means that the machine will have paid for itself when 150 boxes have been welded. While this saving in time is very desirable another important advantage of the manipulator is the elimination of the safety hazard caused by handling the boxes with a crane and blocking them to get them into position for welding.

Now as to the advantages of the welded boxes. By far the most important one is the low initial cost compared to the cast steel boxes we had been using. Being 700 lb. lighter than the cast steel boxes there is a considerable saving in power consumption and wear and tear on the charging machines. These advantages are almost impossible to evaluate in dollars and cents, but certainly the saving is considerable. So far we have about 250 welded boxes in service out of a total of 500. As yet we cannot say what the life of these welded boxes will be, but by all indications they will have a longer one than the cast steel boxes.

After having these boxes in service for about two years there are two improvements suggested on the next boxes we make, both of which are on the cast steel

Figure 3—Charging machine lock bars may be made by welding a forged hard-surfaced end on a length of hot-rolled stock.

Figure 4—Charging machine rams may be hard-surfaced at the engaging end, while the body is surfaced with stainless steel.



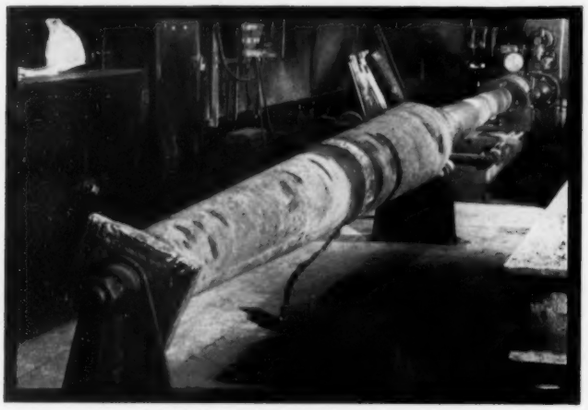


Figure 5—View showing fixture for aligning and rotating the work when welding a new end on a ram.

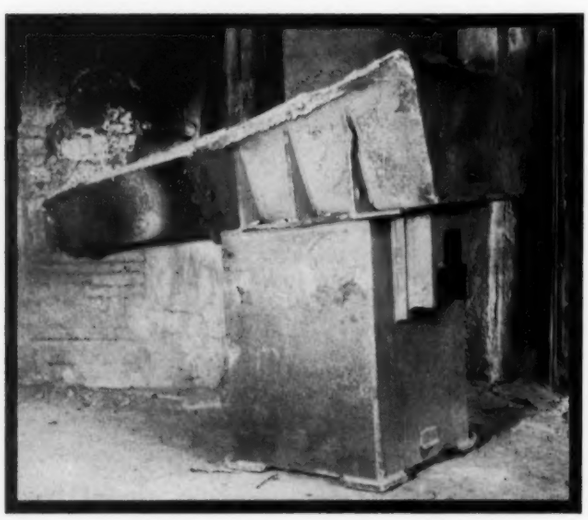
head. The present heads have square edges on the top; this will be changed to a 1¼ in. radius to make a round edge on top. The purpose of this change is an attempt to stop the cracks that occasionally start at about the middle of the head and gradually grow downward until they reach either the lifting hole or the lower hole where the lock bar engages the box. The other change will be to cast a J welding groove on the head so the main plate can be attached to the head by a butt weld on the outside and a fillet on the inside instead of two fillet welds as we have done in the past.

CHARGING MACHINES

About two years ago we had accumulated three broken charging machine peels. Two of these peels had broken through the keyway in the taper end, the other one had broken off at the base of this taper. It was necessary to repair or reclaim these peels or have new ones made at a cost of about $1200 each. It was not practical to repair the peels so we decided to try welding the ram directly to the peel, thus making the peel and ram into a single unit (Figure 2). The first one we reclaimed was thermit welded. This proved to be entirely satisfactory in service, however, the cost of the thermit welding seemed rather high and it was decided to try electric welding. The electric welding was somewhat cheaper and proved to be as satisfactory in service, so the remaining peel was welded to a ram in the same manner.

While the original purpose of this welding job was to save the three broken peels, it also made unnecessary the use of the large taper keys that are customarily used in holding the ram on the peel. These keys are constantly working loose and require tightening at frequent intervals. Also over a period of time a considerable number of new keys are required.

Figure 6—View of hot metal runner, with box base of welded construction.



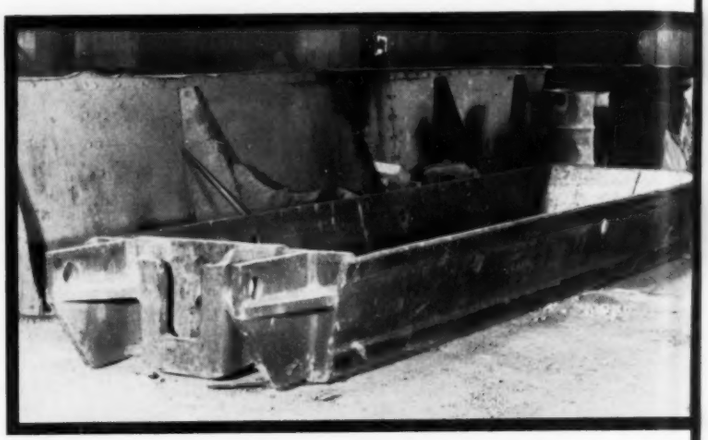


Figure 7—Brick trays, of welded construction, greatly reduce the handling of brick.

The rams and peels welded into a single unit have been so satisfactory that we have since welded all our rams and peels into a single unit. When welding a ram to an unbroken peel the end of the ram is heated and shrunk on the peel. This insures perfect alignment with very little labor.

While we saved three peels which was quite an item the most important saving in the long run will be the entire elimination of the tapered keys and the necessity of constantly tightening keys that have worked loose.

WELDED LOCK BARS

The charging machines in use at our plant require a lock bar about 26 ft. long (Figure 3). This is expensive when made of forged steel, as is common practice. Our standard practice now is to forge the end of the bar that engages the charging box, making it about 4 ft. long. The necessary machine work is then done on this piece and the end undercut to receive the hard facing

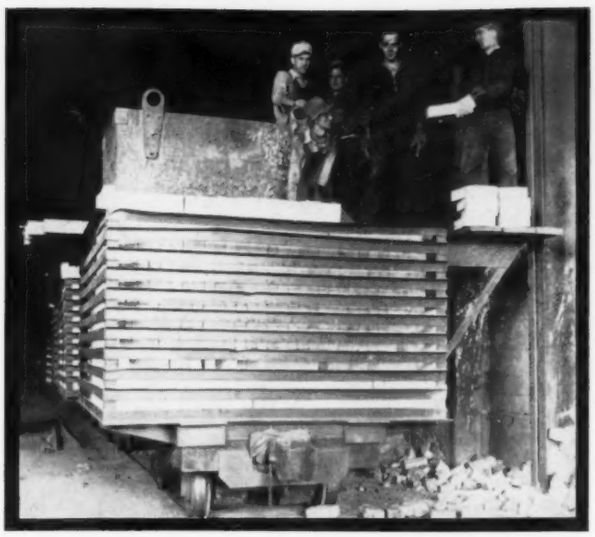


Figure 8—Welded brick racks built on charging buggies also effect a saving in brick handling.

material. After this is completed the forged piece is electric welded to a piece of common hot rolled steel bar 1½ in. in diameter and of the required length.

When we first started making this type of lock bar considerable trouble was experienced with the 1½ in. bar breaking off at the edge of the weld. This trouble was eliminated by stress relieving with a torch as soon as the welding was completed and then grinding with a hand grinder. The purpose of this grinding was to eliminate the point of stress concentration set up at the edge of the weld.

The first bars we made were put into service in the "as welded" condition. These bars had an average life of about four days, the failure occurring at the end of the weld. Stress relieving with the acetylene torch increased the average life to about three weeks. However, the failure was still a fatigue fracture starting at the edge of the weld, the same as in the untreated bars. The next group of bars was stress relieved and ground as described previously. This procedure practically eliminated failure of the bars at the weld. Bending from overheating now is the most common trouble, in which case they need only to be straightened to be ready for service again, or by wearing pointed at the end where they engage the charging box, in which case they can be hard faced again and put back into service. This case illustrates very clearly the necessity of eliminating abrupt changes of section wherever reversal of stresses occurs.

PROTECTION OF RAMS

Failure of the ram is generally due to heat checks that develop from the head, to a point about 3 or 4 ft. back from the head. In an attempt to retard the development of these cracks, two rams have been coated with 25-12 stainless steel about 4 ft. back from the head (Figure 4).

When the rams are received from the steel foundry they are put in the lathe and the end bored for the lock bar. While set up in the lathe that portion of the head that engages the charging box is turned down to take a ⅛ in. layer of hard facing. The hard facing is done with a ⅛ in. diameter electrode depositing a metal equal to high speed tool steel. The area that has been hard faced is then gone over with a hand grinder to take off the high spots. This type of electrode has proved the most satisfactory of several we have tried for this purpose. This electrode gives a good life and has the advantage that it can be deposited in the vertical position, thus making it possible to build up a ram while it is in place on the charging machine.

The portion of the ram to be covered with stainless steel is first descaled and then sand blasted in order to secure a clean surface. The weld beads are deposited longitudinally using $\frac{5}{32}$ in. diameter electrodes with about 140 amperes. It requires between 60 and 65 lb. of stainless steel electrodes and 45 man hours of labor to face a ram with stainless steel. These rams have not been in service to tell what results we will have.

In welding a new end on a ram we use the electric arc rather than thermit welding. We have welded a number of them with thermit and they were entirely satisfactory, but we find electric welding much cheaper and just as serviceable. In our repair shop we have set up a permanent fixture for rotating and aligning the two pieces of the ram. The speed of rotation is about the same as the forward speed of the arc and can be started and stopped by the operator, using a foot pedal. (Figure 5)

LOW SPOTS IN RAILS

Another welding job on the charging machine that is rather simple but saves considerable time is the building up of the low spots that develop in the rails on the charging machine bridge, caused by the starting and stopping of the trolley.

To build up these low spots, the battered metal is first chipped away. A layer of 25-20 stainless steel is then put on and the balance of the depression built up with a coated 13 per cent manganese electrode. The coated manganese rod is used instead of the bare type because it can be better controlled and thus reduce to a minimum the grinding necessary to dress the rail.

This method has proved very satisfactory and rails built up in this manner last longer than new ones.

HOT METAL RUNNERS

The hot metal runners in use at our open hearth up until several years ago were of such a design that the spout end had to be rested on the door bank. This practice often resulted in broken door banks with resultant losses. In order to prevent these troubles a new hot metal runner was designed with the following points in mind. First, it must be well balanced so it can be set in place in front of the furnace without touching the door banks; second, the spout shall be easy to replace; third, it shall be easy to "skull" without harming the brick lining; fourth, the head for picking up

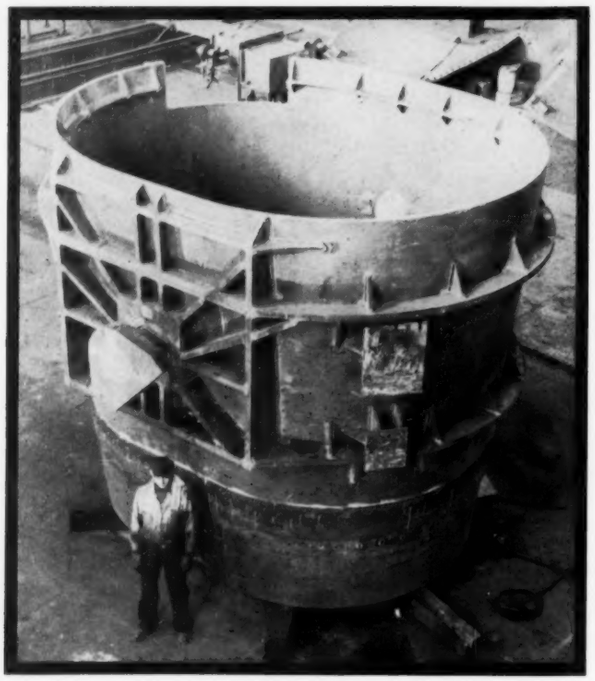


Figure 9—This 190 ton open hearth ladle, of welded construction, is 12 ft. 9 in. deep, 15 ft. 6 in. long, and 14 ft. wide.

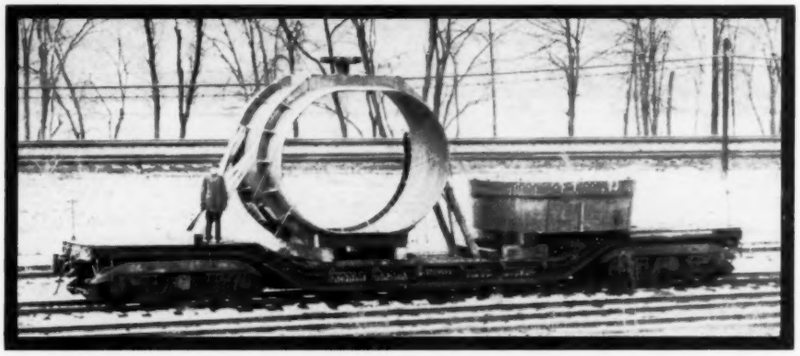


Figure 10—The ladle shown in Figure 9 was built in two parts in order to ship it.

the runner shall be so arranged that hot metal cannot splash on it and cause trouble in picking the runner up with the charging machine.

The first runners we built had tripod supports. The tripod stand was used in order to secure a solid footing on the irregular floor in front of the furnaces. The renewable spout is connected to the main part of the runner by six 1 in. bolts. A new end can be put on a runner without disturbing any of the brick work in the main part of the runner. All the sides are sloping so the skull can be removed with a magnet without injuring the brick work. The receiving end of the runner extends well back over the grip plate. This location of the grip plate or lifting head makes it almost impossible for hot metal to splash and clog up the grip plate. The ram of the charging machine engages the head from the bottom instead of the top. This further insures the head being kept free of any obstructions.

Two runners were built with the tripod base and the only trouble encountered was the difficulty of keeping the legs free of splashed metal. This was remedied by replacing the tripod stand with a box as shown in Figure 6. All of our hot metal runners are now of this type and since adopting this design we have not had a single broken door bank due to the hot metal runner.

Figure 11—This ladle, of 140 tons capacity, is elliptical in shape with dished bottom and no bottom bracing.

WELDED BRICK TRAYS

Figure 7 shows a large welded brick tray for catching roof brick when knocking down a furnace roof.

A standard cast steel head, as used for the charging boxes, is welded into the end of the box and well braced. The balance of the box is constructed from plate and angles. This box may look rather large to be handled by the charging machine, but the only time the charging machine really picks the box up is when it is placed in the furnace. After the tray has been filled with brick the charging machine merely pulls the box out of the furnace to the point where the floor crane can get hold of it.

These trays are made in several different sizes. When a new roof is to be put on a furnace the door and door frames are removed and these trays are slipped in between the buck stays, the distance between buck

stays governing the width of the trays. Four or five trays are put in the furnace, thus covering almost the entire bottom. The roof is then knocked down and the bricks are caught in these trays, thus eliminating 75 or 80 per cent of the handling of brick.

BRICK BUGGIES

Figure 8 shows a welded brick rack built up on a charging buggy. The folding scaffold near the top is of such a width that when the car is on the narrow track in front of the furnace and the scaffold is lifted it comes right up to the furnace. There is a siding in the brick shed where these cars are loaded and then taken directly to the open hearth and spotted in front of the furnace that is being repaired. These cars have eliminated a large amount of handling of brick as compared with the old method of handling brick.

REPAIR OF SLAG BOWLS

In the repair welding of slag bowls care should be taken to secure a 100 per cent weld the full thickness of the broken section. We burn and chip a double V the entire length of the break, taking special care to see that the end of the crack has been reached. Welding is started at the end of the groove and using the step-back method the weld is built up to full section in steps about 8 in. long. The root of the weld is chipped to good metal before finishing the back of the weld. The welds are built up flush with the surface of the bowl and no reinforcing of any kind is used.

In my opinion reinforcing straps or plates of any kind are actually harmful due to the fact they set up stresses due to temperature differences and non-uniformity of section at the joint.

This method of repair takes more time than some others, but it has proved 100 per cent satisfactory in service and is the cheapest method in the long run. The bowls should be watched and any cracks that develop should be repaired as soon as they reach a length of one or two ft.

Broken frames on slag cars are repaired either by thermit or arc welding, whichever is the most desirable method in the particular case.

TRUCK FRAMES FOR INGOT CARS

A considerable number of truck frames for the ingot cars are repaired by arc welding. These are steel castings and very often the failure occurs through a section where shrinkage cracks or cavities have occurred. In repairing these castings the break and flaws in the casting are well chipped out and welded from both sides, chipping out the root of the first weld before starting to weld the second side. This repair work has been very satisfactory, resulting in the saving of a large number of broken castings. The repaired castings give just as good and in many cases a better life than new ones.

WELDED LADLES

Within the last year at Steelton we have built 10 all-welded ladles. Eight of these ladles had a capacity of 190 net tons and were built for the Sparrow's Point plant (Figure 9). The other two were of the 140 net ton capacity and were built for the Cambria plant at Johnstown. The 190 ton ladles for Sparrows Point are the largest ones in the company, and I believe in the country. Bethlehem has about 50 all-welded ladles in use in its various open hearths, all giving excellent service.

Figure 10 shows one of the ladles loaded, ready for shipment to Sparrows Point. It was necessary to build the ladle in two parts in order to ship it. The two parts are joined by a riveted butt strap 1⅛ in. thick and 22 in. wide, with 150 1¼ in. diameter rivets in each section. The sections are riveted together in order to eliminate the necessity of stress relieving after assembly, which was impractical in this case.

This ladle is 12 ft. 9 in. deep, 15 ft. 6 in. long and 14 ft. wide. The weight of the ladle complete, without the lining is 60,000 lb. About 2500 lb. of electrodes were used in the fabrication of each ladle.

The two ladles built for Johnstown (Figure 11) were of a much lighter and I believe better design. It is elliptical in shape with a dished bottom without any bottom bracing either inside or out.

In order to make the dished bottom a standard circular dished head was secured. This was then cut in half and a piece of flat plate 17 in. wide bent and welded between the two pieces, with double V welds. After welding the inside the root of the weld was chipped from the outside until good metal was reached. This insures a weld developing the full strength of plate. All the butt welds in the shell plate were made in this manner.

This covers the more or less special or new welded jobs in our open hearth department. There is the regular run of repair work that turns up every day, such as repair of furnace doors and door frames.

It has been our experience that to keep up with the routine welding in the open hearth it takes a welder for each three furnaces that are operating. Up until about two years ago all welding in the open hearth was done by welders from one of the maintenance departments. At that time a welder was put on the open hearth payroll and the arrangement has proved much more satisfactory, giving a very decided reduction in the cost of open hearth welding.

DISCUSSION

PRESENTED BY

A. W. STEED, *Maintenance Superintendent*, American Rolling Mill Company, Middletown, Ohio

C. C. KEYSER, *Welding Supervisor*, Bethlehem Steel Company, Steelton, Pennsylvania

L. J. GOULD, *Assistant Chief Engineer of Construction*, Bethlehem Steel Company, Bethlehem, Pennsylvania

H. C. BOARDMAN, Chicago Bridge and Iron Company, Chicago, Illinois

A. W. STEED: In our plant we have had a number of cast steel buggies cracked and broken so that they had to be taken out of service. By welding the castings

and reinforcing at the proper points we have been able to salvage practically all of them. The welded and reinforced units have been very satisfactory.

C. C. KEYSER: We have repaired a large number of ingot car trucks very successfully.

A. W. STEED: Do you have much trouble with doors and frames, and if so how do you rebuild them?

C. C. KEYSER: We have the regular run of trouble with doors and frames. When the leaks are due to the plate rusting through or getting so thin it is easily punctured, the material is cut back to where it is thick enough to weld satisfactorily and a patch plate butt welded into the hole. Beyond this we do not do any rebuilding of old doors or frames.

H. C. BOARDMAN: I know very little about the structures to which you are referring although I am very much interested in them, because tanks with which I am familiar are relatively thin as compared with their overall dimensions while these structures are relatively thick as compared with their overall dimensions.

Furthermore, these structures are subjected to rather severe temperature variations such as field welded tanks are not subjected to. For that reason I should like to know whether those welded ladles, for example, give better service than riveted ladles.

C. C. KEYSER: We have every reason to expect a better life from the welded ladles than from the riveted ones. However, the life of a ladle is a matter of years, and as yet none of our welded ladles have reached the end of their life so we cannot make a direct comparison.

H. C. BOARDMAN: May I ask why those ladles are made elliptical in the cross-sections?

C. C. KEYSER: The riveted ladles were circular in cross section and the pit cranes, having two sets of cables and two hooks, were designed for these round ladles. One of the main purposes of the welded ladle is to reduce the weight of the ladle and increase its capacity without increasing the total load on the crane. From the standpoint of good pit practice the depth of the ladle cannot be increased and it is not practical to change the crane. The elliptical cross section is merely the easiest way to increase the capacity and meet all the other requirements.

H. C. BOARDMAN: Are all of these ladles stress relieved?

C. C. KEYSER: Yes.

H. C. BOARDMAN: Do you have any that aren't?

C. C. KEYSER: No, they are very cautious about hot metal ladles. We have the facilities for stress relieving them after welding and we have not tried using any without stress relief.

Discussion--HARDENING *of* INSIDE DIAMETERS BY INDUCTIVE HEAT TREATMENT

(*Continued from page 51*)

dated. The cost of building the necessary apparatus to do these small diameter pieces is so much greater than for the larger tubes that little data is available on the heat treatment of such parts.

RAY LOUDEN: Can you heat a strip, say a thin gauge continuous strip by putting it partially around a roll?

H. E. SOMES: Almost anything in the heating line can be done by induction heating.

C. S. BULLIONS: Is there steam in connection with this induction heating?

H. E. SOMES: There is a little, but of so short duration you hardly see it.

S. L. GOODALE: The success of this method of case hardening seems to me very surprising, although perhaps less so than the success of the flame hardening of gear teeth.

Steel contracts during cooling and expands during heating, through wide ranges in temperature except that it expands briefly during cooling and contracts briefly during heating through the transformation range. It is somewhat hard to visualize how these internal volume changes can be accommodated without starting quenching cracks. The space within which they occur is rather narrow; and moving much as a wave with perhaps a little of wave characteristics inside the metal. Somewhat high locked in strains can be expected in such treatment, and my surprise has been that experience has shown such strains by and large to be within what the metal can stand. Since the first announcement of induction heating by high frequency currents I have believed that the method would have many important applications. Mr. Somes is to be congratulated for his realization and perfection of some of the possible ones

DIESEL SWITCHING EQUIPMENT for Steel Plants -

By E. M. Smith

Assistant Sales Manager

ELECTRO-MOTIVE CORPORATION

LA GRANGE, ILLINOIS

Presented before the A.I.S.E. Annual Convention
Chicago, Illinois, September 24-27, 1940

▲ OUR records show that the first diesel switching locomotives entered service in 1925, and the number in railroad and industrial work by years to and including 1939 follows:

Year placed in service	Less than 300 hp.	300 hp. to 600 hp.	600 hp. to 900 hp.	900 hp. to 1000 hp.	1000 hp. and over	Total
1925	..	2	1	..	..	3
1926	..	8	2	..	..	10
1927	..	3	2	..	..	5
1928	..	7	3	..	..	10
1929	..	7	2	..	..	9
1930	..	52	8	..	..	60
1931	..	15	2	..	..	17
1932	..	..	3	..	..	3
1933	3	4	6	..	..	13
1934	2	4	8	..	..	14
1935	1	5	18	1	..	25
1936	..	6	34	..	..	40
1937	7	2	88	42	4	143
1938	10	2	51	30	..	93
1939	2	13	132	7	75	229
Total	25	130	360	80	79	674

This record indicates the rapid growth of diesel usage and the general acceptance of diesel power for railroad and industrial switching, also the very noticeable acceleration in the rate of adoption for the past several years.

By the close of 1940 we believe that not less than 1000 diesel locomotives will be engaged in switching, of which approximately 150 will have been taken for steel plant and connected switching, indicating that the steel industry in general has adopted the diesel for switching purposes and fully recognizes their advantages as compared with other types of switching power.

It is noteworthy that in the past four years the railroads, largest users of switching locomotives, approximating a total of 12,000, rarely purchase other types of power and many of them have adopted the policy of retiring steam locomotives as heavy repairs become necessary and replacing such steam equipment with diesel locomotives.

Sizes and Applications—We, and manufacturers generally, provide these diesel switchers in the following standard sizes:

Approximately 300 hp. type—Approximating 44 tons on drivers and equipped with mechanical, hydraulic or electrical transmission.

Approximately 600 hp. type—100 tons on drivers, electrical transmission.

Approximately 1000 hp. type—125 tons on drivers, electrical transmission.

Such standardization of sizes fits nearly all classes of switching service and has helped to create the present trend to diesel power. As a result of this standardization in sizes, lower production costs and prices for the equipment have followed to the consequent benefit of users and the general adoption of diesel power.

Switching Characteristics—All of the weight of the diesel locomotive is carried on the driving wheels with uniform torque exerted by an electric motor at each driving axle, giving the most effective return from the locomotive weight, and producing high starting tractive effort. The diesel engine, which constitutes the prime mover, delivers full rated horsepower at all speeds, the power generated reaching the driving axles through electric transmission.

In switching operations, the average speed rarely exceeds six or seven miles per hour, and within or above this range, the full horsepower is always available. With steam locomotives on which the cylinders are direct connected to the driving wheels, only a relatively small portion of the potential horsepower is available at such switching speeds. On account of these fundamental differences in characteristics, we frequently find 600 hp. diesel switching locomotives giving a better all-around switching performance than steam locomotives rated as high as 2000 hp.

Availability—Diesel switchers should normally be available for 8000 hours of work yearly, or 330 days of 24-hour service. Our type of diesel carries sufficient

The modern diesel locomotive has effectively proven its operating advantages and economies in steel plant switching service as well as in other fields.

fuel oil for four or five days' operation of 24 hours each, and of course sufficient water for several weeks' service.

Steam locomotive abailability is relatively low due to the necessity of more frequent and extensive repairs and inspections, also services such as fire cleaning, fueling, watering, boiler washing, etc., with the result that they are rarely available for more than 6000 hours yearly. This greater availability generally makes it possible for diesels to replace more than the same number of steam locomotives, and on present day prices of both types of equipment, more than equalizes the slightly higher diesel first cost per unit.

Flexibility—Diesels will generally operate anywhere a revenue freight car may be handled, so combining the flexibility of the small 6-wheel steam switcher with the greater capacity of the 8-wheel steam switchers which are frequently restricted on account of their long rigid wheelbase, and concentrated weight on drivers. This ability to do the work of either class of steam switcher makes the diesel capable of performing a more complete service, and is a further factor in reducing the number of locomotives needed, also the locomotive hours required in the handling of some switching services.

General Efficiency—The mentioned higher diesel tractive effort at switching speeds, exact power control at all speeds, short rigid wheelbase, better weight distribution, freedom from the mentioned operating delays inherent in steam equipment and better visibility for signal observation, have the combined effect of speeding up switching operations.

Safety and Suitability—Diesel low hood design provides visibility in all directions. This feature, coupled with the absence of smoke and steam which so frequently obscure the view of the operator of steam locomotives, makes for improved signal observation and greater safety. The diesel eliminates the firebox and boiler which are natural hazards. The short rigid wheelbase and swivel truck arrangement provide very comfortable riding qualities, and as diesel handling is accomplished with very little physical exertion there is less fatigue, and the operators are able to fully and better concentrate on signals. Also with diesels, the fire hazard is negligible.

These characteristics are particularly helpful in steel plant switching. The visibility permits successful and safe operation with one man, as there is no practical necessity for employment of firemen.

The absence of smoke and cinders permits free operation within buildings where steam smoke is objectionable and damaging to many processes of steel manufacture and to employees such as overhead crane operators and workmen generally.

Track Wear Characteristics—The elimination of reciprocating parts, better weight distribution, short rigid wheelbase, and uniform power application make the diesel much easier on track, effecting very substantial economies in this item. Derailments with attendant service delays and expense, are with diesels very infrequent as compared with the common steam experience.

Fuel Economy—Diesels normally effect a reduction of approximately 75 per cent in fuel expense as compared with the cost of steam power, and this saving follows the inherently high thermal efficiency, injection system, and the elimination of all fuel consumption during periods in which the locomotives are not being operated. In typical switching operations, we have found that one tank of fuel oil covers the same number of service hours as twelve cars of coal.

Servicing Facilities—The service on diesels is negligible, there being no necessity for attendants for fire cleaning, handling ashes, cleaning grates, maintaining boiler water levels, etc., while the engine is not in service, or for the periodic boiler washes and inspections which are expensive on steam locomotives on account of firebox and boiler.

Maintenance—The design and construction of the diesel locomotive make for low maintenance costs and for performing the necessary repair work with the minimum of time out of service. With diesel engines, all parts are relatively light, easy to handle, and subject to quick inspection and rapid repair or replacement. The diesel locomotive has no tender to maintain or parts such as the boiler and firebox, overhaul of which means complete dismantling of the locomotive. From our experience, we have concluded that ordinarily the hourly repair expense on diesels for each year should not be more than 50 per cent of that on a steam locomotive of corresponding age. As compared with the average age, in excess of 25 years, of steam locomotives now used in railroad and steel plant switching, the ratio of immediate diesel saving is naturally much greater.

Water—With a diesel, the water consumption is negligible. With steam, the average cost approximates 8 cents hourly exclusive of the substantial cost of maintaining water stations.

Retiring Steam Facilities—Diesel maintenance, servicing and fueling facilities are relatively inexpensive, compact, safe and time saving in operation, and infrequently used. The more extensive steam facilities may often be retired and release valuable space for production purposes.

Summary of Economies—The combination of diesel advantages in the items of fuel, water, servicing and repair expense, creates substantially the following picture of comparisons in the hourly cost of operation—

600 hp. diesel and the typical six-wheel steam switching locomotive.

Item of hourly expense	600 hp. diesel switcher	Typical steam locomotive	Hourly diesel saving
Fuel.....(1)	$0.25	$1.05	$0.80
Locomotive repairs...(2)	0.50	1.00	0.50
Roundhouse expense..(3)	0.05	0.20	0.15
Lubricating oil.....(4)	0.05	0.02	−0.03
Other lubricants and supplies.....(5)	0.02	0.02	....
Water.....(6)	....	0.08	0.08
Enginemen.....(7)	0.95	1.70	0.75
Total hourly cost.....	$1.82	$4.07	$2.25

1) Diesel basis 5 gallons fuel oil hourly at 5 cents per gal. Steam basis 700 lb. coal at $3.00 per ton.
(2) Diesel includes provision for periodic overhaul. Steam based on maintenance of steam engines 25 years old.
(3) Diesel engines require but little servicing. Steam engines require fire cleaning, boiler washing, watching and expensive inspection on account of safety regulations.
(4) Diesel estimated at less than one (1) pint lubricating oil hourly, including periodic complete oil changes.
(5) Diesel water consumption negligible.
(6) No "practical" necessity for "firemen" on diesel locomotives in the normal steel plant operation.

On the basis of the locomotive working 8000 hours, annual economy approximately $16,000 in comparative hourly expense only. This saving is sufficient to liquidate investment within five years and, in addition, gives other very important benefits such as:

(a) Handling of switching work in less hours and with less locomotive units.
(b) Greater safety.
(c) Reduction in fire hazard and smoke damage to manufacturing processes and complaints from employees within buildings which locomotives enter.
(d) Less track wear and fewer derailments.

A recently compiled study of diesel locomotives working a total of more than 2,700,000 hours in general railroad service and steel plant switching, shows the following performance statistics:

	600 hp.	900 hp.	1000 hp.
Average availability for service, per cent.....	94.3	93.7	93.4
Average hourly fuel oil consumption (gal.)....	4.61	6.53	7.10
Average hourly lubricating oil consumption (pints).....	0.96	1.54	0.86
Average hourly repair and inspection expense (cents).....	26.8	38.9	35.4

Standard Sizes—Our company now offers these switching locomotives in three standard sizes, 300, 600 and 1000 hp. A general description of these locomotives is given in Table I.

Depreciation—Railroads generally figure depreciation at 20 years. Some railroads which have already been operating diesel locomotives for years are of the opinion that this estimate is low and the depreciation life could well be extended. However, we feel that 20 years is a proper estimate recognizing the factor of obsolescence as well as depreciation.

Age of Steam Locomotives—The steam locomotives on the railroads assigned to switching service have average age of 25 years and such switching operations are commonly regarded as the "back yard" of the railroad picture on account of not keeping the power modernized.

If 25 years is the average age of switching locomotives in railroad service, my guess is that the average age of switching locomotives in the steel industry is at least 30 years, as it has long been the rather common practice for the steel industry to take second hand steam locomotives from the railroads.

I have noted many cases where steam locomotives built 30 and more years ago are still endeavoring to meet modern switching requirements about steel mills. It has seemed to me that the switching operations of the steel mills are regarded as a necessary evil and in some cases not even necessary.

It always has appeared to me that large sums of money are spent for providing the latest in plant facilities and every effort made to have the cheapest possible sort of switching power assigned to serve it. It has been my experience that cheap switching power really is about the most expensive to operate, as what is saved in capital investment is lost many times over in high hourly operating expense, including the necessity of having more locomotives working and working for more hours than would be required if modern diesel units were assigned.

Oil Burning Steam Locomotives—We find that while but 11 per cent of the railroad switching is performed by oil burning steam locomotives, actually this small number of locomotives is using more fuel oil than would be needed if all of the forty-one million hours worked annually by railroads in switching, were dieselized. It

View of shop production line, showing various stages in the assembly of diesel switching locomotives.

is therefore evident that from a national economy viewpoint, the dieselization of all switching operations would actually reduce the amount of fuel oil taken.

We find that one tank car of fuel oil assigned to diesel use will cover as many locomotive hours as fifteen tank cars of fuel oil assigned to oil burning steam locomotives.

Conclusion—It seems to me that the advantages which the diesels offer for the switching operations of the steel industry are very well summarized in an article which I recently read describing the results obtained by a steel plant in switching with diesels, as compared with the former steam experience. This article read as follows:

"The smoke and the puffing, chugging glamour of the steam locomotive is leaving us, as are the cinders that got into our eyes. The modern diesel-type locomotive—the kind used to power the great new streamlined trains—has come to the steel mills.

"The railroad is solving transportation problems with six of these powerful diesel locomotives which are used to haul hot metal ladles and to move coke onto the highline over blast furnace bins.

"It seems almost miraculous to watch one of these new locomotives pull past the switch points at 86th Street with a string of seventeen or eighteen loaded cars, quietly reverse, and take them easily and noiselessly up the high-line. It is so startling, because a week or so before we were in the habit of seeing the steam locomotive go almost as far as 81st Street to get a good run and make the grade with only seven cars. Hooking onto a string of ten hot-metal ladles at the blast furnaces (the steam-type handled five), the new locomotives are able to move away steadily. The smooth, almost effortless pull of these diesels is easy on equipment, too.

"So economical are these new 'iron horses' that their 600 hp. uses but five gallons of their 600-gallon fuel capacity each hour of working, or approximately one hundred gallons per day. This efficiency and capacity enables large savings because of the shortening of refueling time and elimination of time spent in the round

TABLE I.

GENERAL DATA

	300 hp.	600 hp.	1000 hp.
Track gauge, ft.—in.	4—8½	4— 8½	4— 8½
Length over coupler pulling faces, ft.—in.	24—1½	44— 5	44— 5
Width over side sills, ft.—in.	10—0	10— 0	10— 0
Maximum height above rail, ft.—in.	13—4½	14— 5	14— 5¾
Platform height above rail, ft.—in.	3—7	4— 7½	4— 8¼
Height of cab floor above rail, ft.—in.	6—5½	6—10	6—10¾
Length of operator's cab, ft.—in.	6—6	6— 6	6— 6
Width of operator's cab, ft.—in.	10—0	9—11½	9—11½
Height of power plant hood roof above rail, ft.—in.	9—6⅛	11— 8	11— 8¾
Width of power plant compartment, ft.—in.	5—7	7— 0	7— 0
Wheelbase, truck, ft.—in.	13—0	8— 0	8— 0
Truck centers, ft.—in.	.....	22— 0	22— 0
Number of drivers, pairs	2	4	4
Diameter of drivers, in.	40	40	40
Size of journals, in.	6½x12	6½x12	6½x12
Minimum curve radius, ft.—in.	100—0	100— 0	100— 0
Maximum permissible speed, miles per hr.	45	45	60
Total weight (fully loaded), lb.	86,000	198,000	250,000
Total weight (light), lb.	76,000	191,000	243,000
Weight on drivers, per cent	100	100	100
Journal load per driving axle, lb.	35,000	42,000	56,000
Gear ratio	15:62	15:62	15:62
Capacity: Starting T.E. at 25 per cent adhesion, lb.	21,500	50,000	62,500
Supplies (approx.):			
Fuel oil, gal.	450	600	600
Cooling water, gal.	50	125	200
Lubricating oil, gal.	40	75	130
Sand, cu. ft.	20	28	30

house for washing out of the boilers of steam locomotives.

"While we may feel a little sad at the passing of our wheezing, steaming friend, it is progress, civilization, life. It is like the passing of the championship from a slashing bloody fighter to a cool-headed, powerful boxer. The diesel is the new champion, and looks good for a long title-holding reign."

DISCUSSION

PRESENTED BY

I. N. TULL, *Electrical Superintendent*, Republic Steel Corporation, Cleveland, Ohio

A. W. STEED, *Maintenance Superintendent*, American Rolling Mill Company, Middletown, Ohio

I. N. TULL: I can verify approximately the figures Mr. Smith has given as to the economies involved. We have in our plant four diesel locomotives, and they have all given a good account of themselves for a period of five years for some of the engines, and a year on others.

When we first got the diesels we didn't have a place to repair them, and we were a little exercised for fear something might happen and we would need a shop to the extent described here, but as time went on those fears were dismissed, and it was a long time before we had to do any major overhauling of any kind.

We did get some high-lift, motor operated jacks, and I think anybody who has a set of diesel engines should get something on the order of these jacks, because you can get an engine back on the road again in a couple of hours without other facilities for lifting the body off the trucks. If you have to get at the motor or change wheels, or anything of that sort, it might take you a couple of days with hand jacks and cribbing.

A. W. STEED: Mr. Smith has covered the subject very thoroughly, and I think it is an excellent paper on locomotives, probably one of the best we have heard for a long time.

We have had diesel locomotives in our plant for about thirteen years, of the 70-ton and 100-ton class, and they have given excellent results. I think our results verify the figures given in Mr. Smith's paper. Mr. Smith's fuel cost is a little lower than ours, and I wonder what price fuel oil it was based on.

The plants where oil engines have been used for some time have satisfactory proof of the reliability and availability of the diesel locomotives, and their economy in operation well justifies the higher initial cost over the steam locomotive.

We used to talk about diesel locomotives costing $1000 per ton, but that price has come down to about $600 a ton now, so we can approach the management a lot easier than we could several years ago when we asked for a locomotive.

In a plant where the locomotive is not operated on main lines you can use one operator very satisfactorily by putting controls on both sides of the cab, with an indicating light which will tell the ground man from which side it is being operated. One operator does the work very satisfactorily, and that is a big economy.

In most steel plants we are troubled with a lot of curves, and with the old steam engines that meant heavy track maintenance. The diesel locomotives are easier on tracks.

There is one thing we experienced on the bearing between the truck and the main body, which is usually a steel plate on a bronze ring. We found that by replacing that bearing with a roller bearing we increased the life of our flange about fifty per cent, and we also made a very decided improvement in track maintenance.

From the experience of men who have operated diesel locomotives for switching in steel plants, we can justify the claims Mr. Smith has made in his paper.

ABSENCE OF PULSATION *IMPROVES* COMBUSTION

The De Laval-IMO pump favors better combustion by delivering oil to burners uniformly. Its action is like that of a continuously acting piston. There are no valves and no reciprocating parts, nor do the rotors trap oil. The moving members (3) are in perfect rotational balance.

The two geared turbine driven IMO pumps here shown each supplies 90 g. p. m. of Bunker C against 250 lb. pressure to burners on 24-hour service in a central station.

De Laval-IMO pumps are available in all sizes and for all pressures and to handle any grade of oil, from light Diesel to heavy Bunker C. Ask for Publication I-65.

IMO
I MOVE OIL

IMO PUMP DIVISION
of the De Laval Steam Turbine Company
Trenton, New Jersey

LUBRICATION

in its Relation to

MAINTENANCE

By C. W. Phillips and R. A. Barta

Presented before the A.I.S.E. Annual Convention
Chicago, Illinois, September 24-27, 1940

▲ MODERN development of lubricants and lubrication methods with the ever increasing installations of more expensive bearings and gears has warranted full time individual supervision of lubrication practice. Whereas some of the large plants in the steel industry had the foresight to realize the importance of correlating maintenance with a lubrication engineer, in recent years many of the smaller units have advanced in this respect.

Whether or not a lubrication engineer is employed, this paper will endeavor to point out the importance of his duties and the value of his contribution to the maintenance program in any plant. It is difficult to establish qualifications for an engineer of this type. He should be familiar with mechanics, and any actual experience maintaining machinery would be of great aid when going into such a position. A certain amount of technical information dealing with lubricants can be of value if any recommendations in lubricants are to be made. However, knowledge of the most practical properties of any lubricant can only be obtained by actual observation and experience. By far the most important personal qualification of a lubrication engineer involves diplomacy in his dealings with practically every superintendent in the plant. The job can be eased considerably if a department head will set definite regulations for his foremen concerning any proposed changes in lubrication practice or pointing out any sources of trouble. All in all, a definite understanding on all problems involving lubrication should provide a harmony that would appear in reduced maintenance costs.

Any new mill or machinery is selected to perform a certain amount of work or produce a product of a certain quality over a specified period of time. Because it is realized that no machine can run indefinitely, allowance must be made for shutdowns and repairs. The procedure for designing a machine usually deals with the selection of proper materials, determination of motion of parts, shape and size, frictional resistance of moving parts, method of lubrication, and economical features in the operation and maintenance of the machine. We can readily note that the extent of maintenance and future repairs on any machine involves an intelligent selection of all these points. Any well designed machine is as good as the amount of time and consideration given to planning a definite method of lubrication under the actual mill conditions. An experienced lubrication engi-

C. W. PHILLIPS
General Master Mechanic
Republic Steel Corporation
Cleveland, Ohio

R. A. BARTA
Lubrication Engineer
Republic Steel Corporation
Cleveland, Ohio

neer called in to the round table at this time can give intelligent recommendations and follow up this work when it gets into the field. Too often, we get machinery where the designer applies some sort of grease fitting or cup at the points of lubrication and lets it go at that.

Any initial survey of lubrication on a machine should include:

1. Checking points drilled for lubrication to see if lubricant will actually reach bearing surfaces.
2. Oil tight cases and lubricant retainers.
3. Accessibility of points to be hand greased.
4. Advisability of installing greasing or circulating oil systems.
5. Checking design of these features for most economical use of lubricants.
6. Clearance and replacement of bearings.

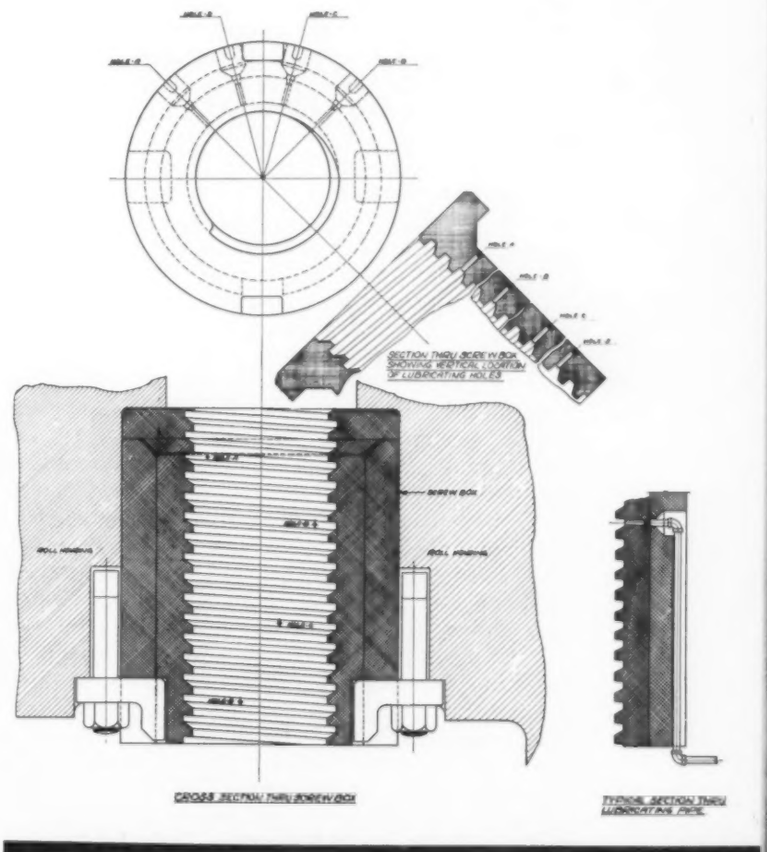
In the first case mentioned we should be on the look out for branching off points on one grease feed. Usually the first few branches get all the grease, and then we get bearing failure or rapid wear. Recently, we had a case in which the slabbing mill nuts and screws were so lubricated. In place of this, four individual points were bored directly into the nut, a cylinder oil with an adhesive additive replaced an extreme pressure grease, and a motor driven forced feed lubricator supplied the oil. Whereas one set of grease lubricated nuts netted 608,000 tons, the present oil lubricated set shows only 15 per cent of the total allowable wear after rolling 311,000 tons. It is hardly possible to give any set tonnage for slabbing mill nuts due to various mill designs and products rolled, but it is probable that screw speed and travel have much effect on the wear. Observations also indicate that the amount of clearance of the thread of the screw has much to do with the life of the screw and screwbox. There should be ample room to allow for expansion when heated up. In addition, dust tight boots around the exposed screw will give longer life to the nut.

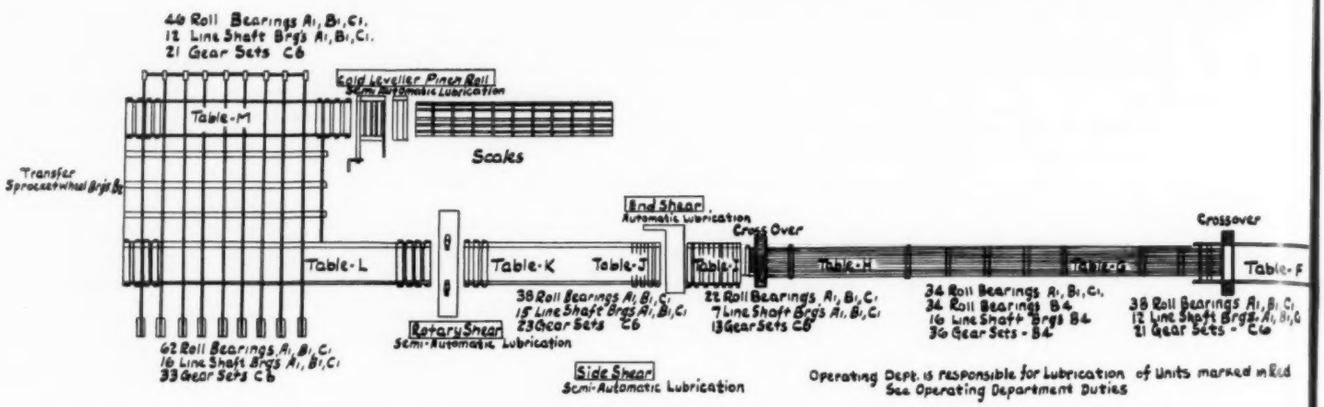
Well designed gear cases allowing use of oil bath splash give excellent lubrication with only a small amount of attention on small gear sets. Although we have some excellent lubricants on the market for painting open gears, there is always more labor involved and we get lubricant around the floor and machinery. Seals go hand in hand with oil cases. On a circulating oil system serving five cold strip pinion and reduction gear sets, after practically three years operation, the oil level in an 8000 gallon storage tank remains about the same due to practically no oil loss. As a definite step toward reducing future maintenance a suggested recommendation of designing for bath lubrication is a step forward.

Placing of grease points for hand lubrication involves careful study. Piping of inaccessible points to headers at convenient locations makes greasing easy when it is decided that hand greasing with a gun is sufficient. A point that is hard to grease whether it is caused by lack of room or moving parts will probably receive less attention than other points better located. Sooner or later a bearing failure occurs, and the machine shuts down, perhaps leaving the mill crew idle. The cost per ton on maintenance increases as well as the operating. While the bearing replaced may not cost much, comparatively speaking, our tons or units per hour stand still for a while and the delay involved is enough to change an otherwise good cost sheet. Too much stress cannot be placed on a careful check on how each frictional point will receive its periodic supply of lubricant.

Lubrication of all large important points usually calls for an application of modern grease or circulating oil systems. The installation of a grease system may cost about $10 per point, but considering the amount of money involved in bearings this is cheap insurance if the system is installed correctly and maintained as well. Any expectation of gaining freedom from bearing trouble by automatic greasing is false if careful consideration is not given the correct installation of the system. After talking automatic lubrication with an open hearth foreman, he finally received a charging machine complete with grease system. A couple of days later he was ready to throw several hundred dollars worth of greasing equipment into a charging box and get out some old grease cups. On checking the difficulty it was found that the system had been poorly installed by the machine manufacturer. Loose connections and broken lines had developed, and grease was being pumped on to the floor. After talking this over with representative of the grease system manufacturer it was found that he had had nothing to do with the installation but that he would willingly make good his system. By repiping this system, securely clamping tubing, and carefully locating the lines no more trouble was experi-

Lubrication of slabbing mill nut and screw by cylinder oil through holes as shown here increased nut life materially.


SECTION THRU SCREW BOX SHOWING VERTICAL LOCATION OF LUBRICATING HOLES
CROSS SECTION THRU SCREW BOX
TYPICAL SECTION THRU LUBRICATING PIPE



enced. This same foreman is now looking for systems on his ladle cranes because this open hearth is making more steel than ever before, allowing practically no time for hand greasing. Keeping up with production here with automatic lubrication is a definite maintenance aid, especially when ingot tons are involved.

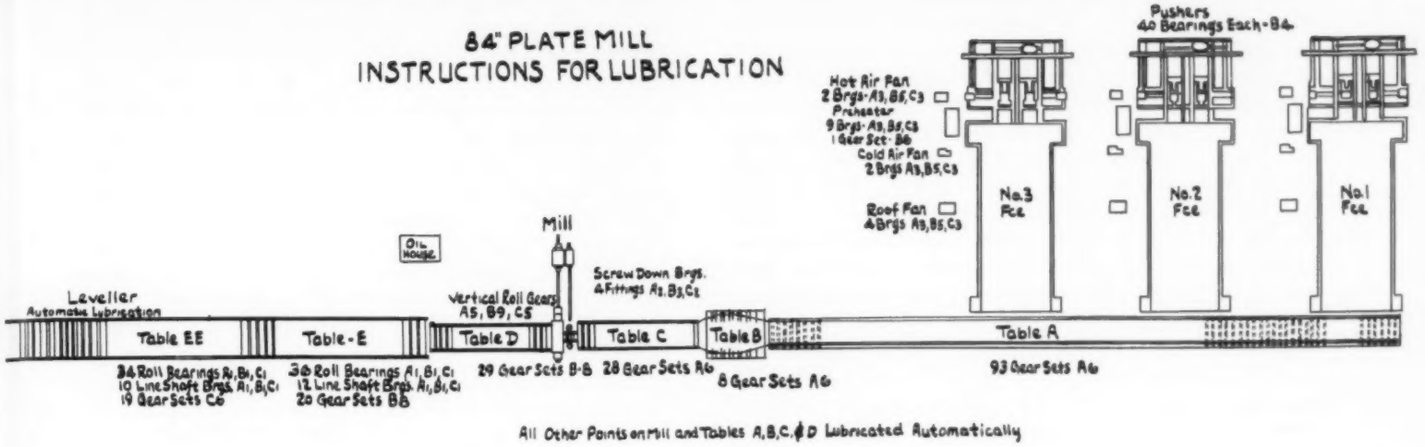
Maintaining grease systems around heavy machinery where scale and water are encountered is a problem. A suggestion to the machine designer where such conditions appear would be to allow for installation of feeders and grease lines by allowing ample protection for their application.

Modern oiling systems especially on modern strip mills seem to have many expensive attachments. A careful weeding out of these before purchase would result in an appreciable savings to the buyer. Also, too many times we get just the opposite, with a tank, oil pump, and piping, and no consideration given to filtration, circulation in cold weather, or proper size and slope on drain return lines. On an important unit in a hot strip mill operating under scale and water a circulating pump pulled oil from the bottom of the case back to the bearings. Frequent trouble was encountered here, until one day a bearing went bad, necessitating a shut-down on the mill. A three compartment oil tank was set at the proper elevation to allow an oil level in the gear case and an ample drain and leg were connected to the bottom of the gear case. The pump was then relocated to circulate oil from the clean compartment of the oil tank. The baffling effect of the compartments has allowed the water and scale to drop out and no more difficulty has been experienced here. This case exemplifies the importance played by single bearings in present mill designs and the added importance attached to obtaining machinery designed for good lubrication under all conditions. Whereas this condition was corrected by a cost of $100 in the field an eight hour delay on this unit due to bearing failure from this cause will not happen again.

Tight circulating oil systems in which the oil is filtered and recirculated offer very economical lubrication costs. The problem confronting the lubrication engineer when talking oil and grease costs with mill men is a difficult one. The usual reply is that bearings cost much more than grease. On the strength of cost sheets for average mills when comparing cost of bearing materials against lubricants we find these to run about the same per ton, and that any reduction of these will show up in an appreciable amount at the end of a year. There are many cases in which a little forethought in obtaining economical consumption of lubricants has resulted in considerable savings. While a single bearing may last for years the periodic supply of lubricant going to it, not including circulating systems, must be renewed at certain intervals. Telescopic oil drains usually lead to waste of lubricant; any place where this can be eliminated by making the case self splash lubricated, perhaps with the aid of fittings to bearings, can lead to more economical lubrication and cleaner mills.

The problem of selecting lubricants for new machinery usually leads to comparison of manufacturers' specifications with the standard lubricants already being used elsewhere in the plant. Too many lubricants usually lead to confusion and unnecessary handling. A modern strip mill lubricant stock includes twelve grades of oil and five grades of grease. This has been found to be amply sufficient to cover all types of lubrication in the conventional strip mill. Initial cost of lubricants, especially for a new strip mill, filling large circulating oil systems and grease lines, can amount to many thousands of dollars. A case like this alone is enough to warrant supervision of selection of the right priced lubricants suitable for the job. There are special costly lubricants on the market that have shown up superior to the straight lubricant. In the majority of applications an average lubricant can be made to perform as well, although we may have different opinions on this. Most bearing trouble encountered is not due to the original grade of lubricant but to contamination with scale and water, incorrect alignment of parts or incorrect clearance, and lack of lubricant at some time or other.

In the foregoing paragraphs we have endeavored to point out some of the various factors in designed lubrication affecting the future maintenance of new machinery. After the machinery is received the lubrication engineer should follow along on the construction, suggesting changes or additions where required, checking



MECHANICAL DEPARTMENT DUTIES
SCHEDULE A

	Operation	Equipment used	Kind of lubricant	Frequency
1	Lubricate roll bearings and line shaft bearings on both sides of Tables E, EE, F, I, J, K, L, and M; and roll bearings on south side of Tables G and H.	Alemite gun	Crank pin grease	Once per turn
2.	Lubricate screw down.	Alemite gun	Crank pin grease	Once per turn
3.	Lubricate furnace pre-heaters, cold air fans, hot air fans, and roof fan.	Zerk gun	Roller bearing grease	Once per turn
4	Lubricate gear reduction unit on pre-heater drive	Spout can	Cylinder oil, Gargoyle compound, or its equivalent	Once per turn
5.	Lubricate vertical roll gears.	Spout can	Gear shield	Once per turn
6.	Lubricate all gear sets on Tables A, B, and C.	Spout can	Gear shield	Once per turn
7	Fill lubricator reservoir on end shear.	Bucket	Crank pin grease	When notified by operator
8.	Fill oil container for clutch on end shear.	Bucket	Oil	When notified by operator
9	Fill lubricator reservoir on side shear.	Bucket	Crank pin grease	When notified by operator
10.	Fill oil container for clutch on side shear	Bucket	Oil	When notified by operator
11	Fill lubricator reservoir on rotary shear.	Bucket	Crank pin grease	When notified by operator
12.	Fill lubricator reservoir on cold leveler and pinch roll.	Bucket	Crank pin grease	When notified by operator
13.	Fill lubricator reservoir on mill and tables.	Pump	Crank pin grease	When necessary
14.	Inspect lubrication on the mill.			Twice per turn
15	Inspect lubrication on Tables A, B, C, and D and hot leveler			Once per turn

MECHANICAL DEPARTMENT DUTIES
SCHEDULE B

	Operation	Equipment used	Kind of lubricant	Frequency
1	Lubricate roll bearings and line shaft bearings on both sides of Tables E, EE, F, I, J, K, L, and M; and roll bearings on the south side of Tables G and H.	Alemite gun	Crank pin grease	Once per turn
2.	Lubricate transfer chain sprocket wheel bearings.	Spout can	Oil	Once per turn
3.	Lubricate screw down.	Alemite gun	Crank pin grease	Once per turn
4.*	Lubricate one furnace pusher	Alemite gun	Crank pin grease	Once per turn
5	Lubricate furnace pre-heaters, cold air fans, hot air fans and roof fan.	Zerk gun	Roller bearing grease	Once per turn
6.	Lubricate gear reduction unit on pre-heater drive	Spout can	Cylinder oil, Gargoyle compound, or its equivalent	Once per turn
7	Lubricate vertical roll gears	Spout can	Gear shield	Once per turn
8.	Lubricate all gear sets on Tables D and E	Spout can	Gear shield	Once per turn
9.	Fill lubricator reservoir on end shear	Bucket	Crank pin grease	When notified by operator
10.	Fill oil container for clutch on end shear	Bucket	Oil	When notified by operator
11	Fill lubricator reservoir on side shear.	Bucket	Crank pin grease	When notified by operator
12.	Fill oil container for clutch on side shear	Bucket	Oil	When notified by operator
13.	Fill lubricator reservoir on rotary shear	Bucket	Crank pin grease	When notified by operator
14	Fill lubricator reservoir on cold leveler and pinch roll	Bucket	Crank pin grease	When notified by operator
15	Fill lubricator reservoir on mill and tables.	Pump	Crank pin grease	When necessary
16.	Inspect lubrication on the mill.			Twice per turn
17	Inspect lubrication on Tables A, B, C, and D and on the cold rolls.			Once per turn

*One furnace pusher shall be lubricated each time this schedule occurs, until all three have been lubricated. On the next occurrence of this schedule, the roll bearings, line shaft bearings, and gear sets on the north side of Tables G and H shall be lubricated. On the three following occurrences, this time shall be devoted to repairs and adjustments of the automatic lubricating systems. In this way, each unit will receive lubrication once each 21 turns of operations or once per week on full operation.

MECHANICAL DEPARTMENT DUTIES
SCHEDULE C

	Operation	Equipment used	Kind of lubricant	Frequency
1.	Lubricate roll bearings and line shaft bearings on both sides of Tables E, EE, F, I, J, K, L, and M; and roll bearings on the south side of Tables G and H.	Alemite gun	Crank pin grease	Once per turn
2.	Lubricate screw down.	Alemite gun	Crank pin grease	Once per turn
3	Lubricate furnace pre-heaters, cold air fans, hot air fans, and roof fan.	Zerk gun	Roller bearing grease	Once per turn
4.	Lubricate gear reduction unit on pre-heater drive.	Spout can	Cylinder oil, Gargoyle compound, or its equivalent	Once per turn
5.	Lubricate vertical roll gears.	Spout can	Gear shield	Once per turn
6.	Lubricate all gear sets on Tables EE, F, I, J, K, L, and M.	Spout can	Gear shield	Once per turn
7	Fill lubricator reservoir on end shear.	Bucket	Crank pin grease	When notified by operator
8.	Fill oil container for clutch on end shear.	Bucket	Oil	When notified by operator
9	Fill lubricator reservoir on side shear.	Bucket	Crank pin grease	When notified by operator
10.	Fill oil container for clutch on side shear.	Bucket	Oil	When notified by operator
11.	Fill lubricator reservoir on rotary shear.	Bucket	Crank pin grease	When notified by operator
12	Fill lubricator reservoir on cold leveler and pinch roll.	Bucket	Crank pin grease	When notified by operator
13.	Fill lubricator reservoir on mill and tables.	Pump	Crank pin grease	When necessary
14.	Inspect lubrication on the mill.			Twice per turn
15.	Inspect lubrication on Tables A, B, C, and D and hot leveler.			Once per turn

IMPORTANT: 1. Lubrication shall be performed in the order scheduled above so that each unit will be lubricated at approximately the same time on each turn. This will insure lubrication on each unit at approximately eight hour intervals.
2. Any irregularities in the lubrication or operation of a unit shall be reported to the millwright on the following turn.
3. The frequency specified above is considered sufficient for normal operation. However, under certain conditions, it may be necessary to perform some operations more frequently, and it shall be the responsibility of the oiler to see that sufficient lubrication is provided at all times.
4. Lubricants are expensive. Care shall be exercised to prevent their excessive use.

OPERATING DEPARTMENT DUTIES
EACH TURN

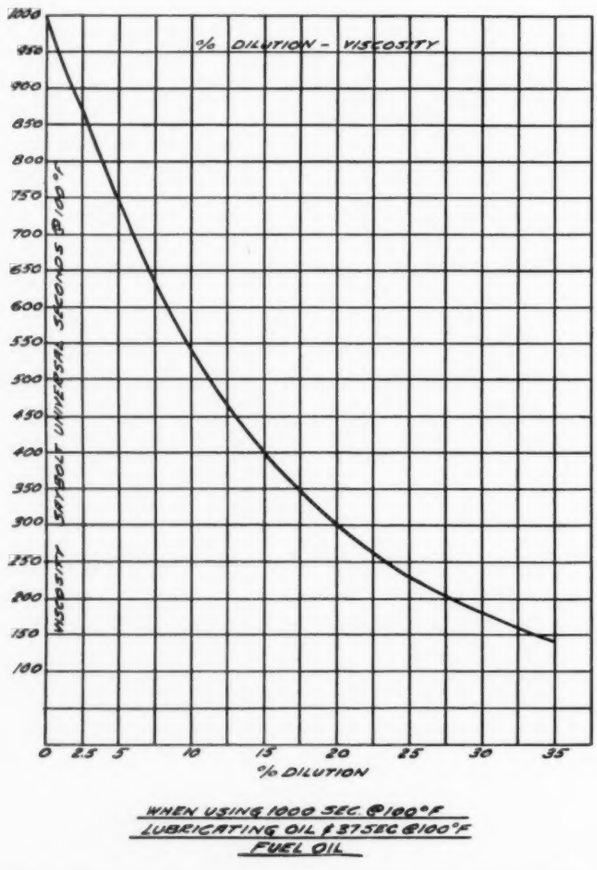
Unit	Method of lubrication	Position responsible	Duties
End shear	Automatic	End shearman	Check lubrication on all parts of the shear. Notify oiler when to fill the lubricator, and clutch oil container.
Side shear	Semi-automatic	Shearman	Operate lubricator pump at two-hour intervals. Check lubrication on all parts of the shear. Notify oiler when to fill the lubricator, and clutch oil container.
Rotary shear	Semi-automatic	Rotary shearman	Operate lubricator pump at two-hour intervals.
Cold leveler and pinch roll	Semi-automatic	Transfer pulpitman	Check lubrication on all parts of each unit Notify oiler when to fill the lubricators.

IMPORTANT 1. Positions shown above are *fully* responsible for the proper lubrication of the unit.
2. Oiler shall be notified a reasonable time before lubricators actually need refilling.
3. Any failure in the lubricating system shall be reported immediately to the millwright.
4. Lubricants are expensive. Care shall be exercised to prevent their excessive use.

cleanliness of gear cases and pipe lines, and supervising the initial applications of lubricants.

In any old or new mill a definite method for determining the schedule of lubrication, indicating all points of lubrication and the personal responsibility for these, should be charted in a clear detailed manner. This usually calls for some time and consideration, involving the foreman, lubrication and industrial engineers. There will probably be many changes after the first chart is detailed but it will be a means to determining the most troublesome points in the mill. Corrections to follow, usually including automatic lubrication equipment, have been made to show definite reductions in maintenance costs and mill delays. In one case in which a study of lubrication was made on an 84 in. plate mill the number of man-hours required to lubricate the mill have been reduced by 50 per cent, this after making a number of small changes and installations after a close study of the mill had been made. The yearly savings made on the cost of changes and new installations, which resulted in much improved lubrication, showed a return of 61 per cent. The mechanical delays in this same mill are running at a figure of only 4 per cent of the previous delays. Much of the savings on delays are due to better lubrication on spots that formerly were neglected or difficult to reach as well as due to the fact that moving machinery is easily lubricated even during operation by automatic grease systems. Better and uniform lubrication saves equipment and reduces repairs to a degree that is not generally thought of. The personal attitude involved in maintaining lubrication means as much as installing automatic lubricating systems. When the oiler is continuously being called off his job to help out the millwrights his attitude begins to reflect the mistaken notion that lubrication is not the most important thing after all. He knows that moving parts of machinery are being neglected and soon sees the eventual outcome of such a mistaken notion: excessive wear, breakdowns, delays. Where the charted method of lubrication is used, men are more interested in the lubrication of the mill and take greater care than they did previously.

Curve showing results of lubrication oil dilution with fuel oil in diesel engine.



The study to determine the most economical manner by which a mill could be lubricated efficiently usually begins with a diagrammatic layout of all parts to be lubricated, including the frequency of lubrication. A time study man is then called in to study how much time is required for each operation. A lubrication chart and schedule is then incorporated with the layout of the mill and put into effect. The mechanical superintendent is responsible for the operation of the system, although operators of certain parts of the mill may be held responsible for their particular portion of the equipment. A good deal has been said and thought about misuse and abuse of machinery by the operators. There are many spots particularly on cutting up lines and shears where the operator could take as much pride in his machine as in the amount of product he turns out.

After a period of time during which the initial lubrication chart has been closely followed, a wealth of information will usually be formed as a basis for suggested recommendations to improve and obtain more efficient lubrication. We may find that certain bearings require applications of lubricant at shorter intervals but that this would be impossible unless the mill were shut down. Here is where some form of automatic lubrication appears, eliminating man hours, increasing bearing life, making small amounts of lubricants perform efficiently and cutting down the mechanical delays. We may find that the oiler would have ample time to cover all his lubrication as per the chart for his turn if he could depend on the operation of his lubricating equipment. There have been many cases where certain types of lubricating equipment should never have been recommended beyond the service station stage. In the case of a sintering plant set-up, two greasers were needed to operate one hand grease pump in order to keep up with the pallet wheels on the sintering bed. Usually much time was wasted trying to get the pump to function correctly. It was then decided to try out a barrel grease pump, air operated, located on the ground floor. A lubricant supply line was piped from the pump, and provisions were made for various outlet valves at convenient points around the machinery. As a result of this small expenditure of money and survey, all machinery can be efficiently taken care of by one man. This particular trouble-free air grease pump has found many other applications throughout the mill. In two years we have yet to hear of a pallet bearing failure due to lack of grease or any mechanical difficulty with the grease pump.

The lubrication survey may reveal that existing

lubrication equipment is mishandled and does not receive the consideration and care that should be given it. In some cases the system may be disconnected, or it is not operated, and manual lubrication is resorted to again. This practice can be condemned, and if it is found that the existing installation has defects, these should be remedied and the system made to work.

Any apparent defects in circulating oil systems can be brought to the surface, if it is found that considerable time is required for the maintenance and inspection of these. A well designed oil system should only entail starting up pumps, together with periodic inspection of oil flow through sight feed glasses. The indication of oil flow to bearings is of paramount importance, and any tendency for using cheap, unreliable oil sight feeds should be discouraged. Periodic tests of oil should be made on all large systems serving important units of the mill, the most practical tests being for viscosity at the operating temperature and carbon residue content. On one large circulating oil system on the back-up bearings of a hot strip mill, the oil operator is held responsible for determining the amount of water in the oil. It is truly remarkable that with all the hydraulic sprays and water on the mill, the moisture content can be kept at a few tenths of one per cent 90 per cent of the time. Oil consumption on this system, although being the most expensive item of lubrication in the strip mill at about 1.9 gallons per operating hour, is truly a tribute to efficient oil seals on these large diameter bearings. Last but not least, some means should be available for providing clean oil to the bearings. Where continuous filtration is not practicable, by-pass depth flow filters with removable cartridges can do much toward prolonging bearing life and eliminating unnecessary labor of cleaning the system. Determination of the source of mechanical trouble can be made without delay if we are satisfied that our systems are 100 per cent all right. The tendency for passing the buck to the type of lubricant used, wasting time experimenting with other types can be eliminated with a little thought toward more efficient systems.

The portion of maintenance cost due to lubricants, bearings, and labor for lubrication may be only about 5 per cent of the total cost of maintenance and repairs. However, these factors might have great effect on the other 95 per cent of the costs especially where delays and breakage result from rapid bearing failure. A record of lubricants and bearing costs for each department following each month's operation can give accurate indication as to where help is needed in the maintenance program and what results are being obtained from a planned lubrication schedule. Below left is a comparison of the lubricant and bearing material costs of various departments over a period of a year (machining or rebabbitting costs not included):

Department	Bearings, cost per ton	Lubricants, cost per ton
Coke plant	.001	.001
Blast furnace	.001	.006
Open hearth	.001	.002
Blooming mill	.017	.011
Billet mills	.003	.020
12 in. bar mill	.009	.015
10 in. bar mill	.008	.015
Total (based on ingot tons)	.02	.028

In most of the cases as outlined above, lubricant costs exceed the cost of bearing materials. The case of the blooming (slabbing) mill involves a modern mill running on more expensive roller and composition bearings but with automatic greasing complete from ingot delivery table to the slab pilers. After the lubrication program is completely in effect here, we can expect better bearing costs and less delays. The source of trouble, upon investigation indicated poor inspection of grease systems and inadequate means for inspecting bearings. Our bearing costs which were broken down to show amounts of roller, brass, and composition bearings also resulted in a new design for feed rollers which were causing delays on numerous occasions. When better bearing life is obtained in this mill excessive lubricant waste will be eliminated.

The billet and sheet bar mill, although very low in bearing costs, shows the waste of lubricant involved where no means of automatic or circulating systems are used. Although the savings in using modern lubrication equipment here apparently does not justify any expenditure, the elimination of much hand oiling labor along with about a 50 per cent reduction in consumption of lubricants should compensate for this.

The lubrication of transportation equipment including plant cars, conveyors, locomotives, locomotive cranes, and automotive equipment should be stressed as much as rolling mill machinery. These units may be in operation for days at a time and unless some specified schedule of lubrication and inspection is organized many costly repair bills will result.

Cars should be scheduled for lubrication at one location at a set time with proper equipment and lubricants being held in readiness and no time wasted. This eliminates tracking down cars, perhaps in hazardous locations and doing away with inefficient lubrication.

With diesel locomotives coming into the picture more and more, lubricant bills when compared to steam locomotives can be much higher unless special attention is given to keeping crank case oil suitable for long periods of time. Very good results are being obtained with depth flow removable cartridge type filters. One diesel locomotive went for nine months before oil was drained from the crankcase. Filter cartridge renewals, based on periodic carbon residue tests, held the oil close to its original cleanliness. With the efficiency of the filter determined, a cheaper naphthenic base oil, which had higher sludging tendencies, was substituted with the same filtration results but at a savings of 50 per cent in cost of lubrication. Improvement in locomotive performance and reduced operating cost resulted. On these same diesel locomotives dilution of the lubricating oil with fuel oil caused rapid thinning out of the lubricant. In order to determine the results of changes to eliminate this dilution, the lubrication blend charts of these particular lubricating and fuel oils were combined and a single curve developed, plotting the viscosity of the mixture against percentage of dilution. It is now a matter of a few minutes' laboratory work to run a viscosity of the crankcase oil and to know how tight the

fuel oil system is and whether the lubricant is too thin for efficient lubrication.

Lubrication of locomotive cranes is difficult, especially when the crane is required to stay in the field constantly and when the operator is working on a bonus incentive plan on tonnage handled. This would be an ideal case for charted lubrication, making the operator responsible for his machine. In one case of a rebuilt crane, the operators on their own accord recognized the importance of allowing fifteen minutes a turn for complete lubrication. Fewer delays resulted in much more tonnage for them and, incidentally, this same crane had fewer trips to the repair shop than other cranes that were lubricated catch as catch can.

One of the most expensive supplies used in maintenance is lubricants. With the ever increasing demand for cleaner mills the conservation and economical use of lubricants demands close attention. There are many devices available for economic application of lubricants. Close supervision of obtaining the right priced lubricants for the job and standardizing and eliminating unnecessary grades can show appreciable savings. In one instance in which this procedure was followed along with the added support of circulating a lubrication engineer around the plant, lubrication costs dropped 30 per cent in one year without the aid of any new lubricating equipment. Several years later, after lubrication equipment had been installed on units using excessive amounts of lubricant, a further reduction of 20 per cent resulted.

Having an adequate batch storage tank available for cleaning highly contaminated oils instead of disposing of these down the sewers is well worth while. Usually a settling period along with subsequent filtration can clean up the oil. Where emulsion with water is encountered long settling periods while heating the oil can eliminate much of the water. One method of blowing hot oil with fairly dry air eliminates practically all moisture in short order.

Fullers earth agitated with used oil has been used successfully to restore clear color and absorb developed acids in used turbine oils. After agitation with the earth the bulk of the earth is allowed to settle and the remainder is filtered out through a fine mesh screen with the help of a filter aid.

The purpose of this paper, while attempting to indicate the importance of lubrication in its relation to maintenance, has cited examples where an improvement in lubrication practice has eliminated delays and shown tangible returns. We cannot just say that lubrication is important. The incentive to more efficient lubrication and the responsibility invested in the man power actually lubricating the production units must be appreciated. With the aid of modern greasing equipment and lubricants now available, the greatest aid toward reduced maintenance costs rests in the hands of supervision. A little thought and planning will go a long way toward obtaining most efficient operation as far as lubrication is concerned.

DISCUSSION

PRESENTED BY

S. F. KITLICA, *Maintenance Supervisor,* Taylor Forge and Pipe Works, Chicago, Illinois

R. A. BARTA, *Lubrication Engineer,* Republic Steel Corporation, Cleveland, Ohio

F. D. JOHNSON, F. D. Johnson Company, Cleveland, Ohio

MAURICE RESWICK, Standard Oil Company of New Jersey, New York, New York

C. E. S. EDDIE, *Lubrication Engineer,* Great Lakes Steel Corporation, Ecorse, Michigan

C. W. PHILLIPS, *General Master Mechanic,* Cleveland District, Republic Steel Corporation, Cleveland, Ohio

HERMAN BERRY, *Assistant Lubrication Engineer,* Carnegie-Illinois Steel Corporation, Gary, Indiana

D. N. EVANS, *Lubrication Engineer,* Inland Steel Company, Indiana Harbor, Indiana

C. R. HAND, *Lubrication Engineer,* Bethlehem Steel Company, Sparrows Point, Maryland

S. F. KITLICA: I have heard your discussion on the lubrication of large rolling mills. I have seen the large mills whose products, billets, plates and sheets, are my company's raw materials. Our forge shop and fabricating machinery is medium heavy and many of the lubrication problems are identical to those of the steel mills.

The steel rolling mill has become a standardized unit and has been greatly improved in the last ten years so that today the oil line is considered the life line of the mill. Machine designers have coöperated with the oil companies and lubrication engineers to give the mills an elaborate and expensive oiling system.

Somewhere in the corner of a machine shop is an old model drill press which will drill the oil hole in a rolling mill bearing for a pipe connection to the lubrication system. This drill press has a grease cup and when the workman thinks his machine needs grease he may do what I have seen done in a good many shops. The grease cup is unscrewed and carried to the oil storage house or corner of a tool room. On his way to the grease barrel the workman picks up a dirty stick or piece of paper with which to scoop up the grease. There is not much that we can do about this problem except to educate the men to the fact that a lubricant must be kept clean in order to keep a machine in good running order; but, it would help me, and perhaps others, to keep our lubricants clean if the covers on the standard size grease drums were made partially hinged. The present type cover is awkward to handle and the drill press workman who is going to drill the oil hole in the mill bearing may not take time to replace it.

R. A. BARTA: Many types of lubricant transfer pumps are available to prevent exposure of lubricant to atmosphere and the possibility of contamination. However, the proper education in developing the oilers' position of personal responsibility can develop thoughtfulness when handling lubricants.

F. D. JOHNSON: I hope that every manager, superintendent and foreman, will carefully study this paper just presented. There are suggestions here, that if followed, will produce profitable results in any mill.

The lubrication engineer is now recognized as a necessity. And the importance of his position is gaining daily with the management, which means that we have today, a high type of engineer and mechanic in this office. Today, he is recognized as one of the key men and is treated as such. The lubricating organization in most mills now consists of several men, and it has taken its place alongside the electrical and mechanical departments. As Messrs. Phillips and Barta state in their paper, the lubricating engineer should insist that his assistants in the various mills must be there for lubrication first and for other duties second. Otherwise, lubrication will suffer.

The lubricating department can save any plant a great deal when they make a study of the mill equipment as outlined in this paper. I know of a big saving on one machine that was made just this past summer, as a result of such a study. A certain type of mill had the main roll bearings lubricated by hand and the heat and load conditions were such that air was continuously shot on the necks. An automatic lubricating system was installed upon the recommendations of the lubricating engineer, who was new on the job. Within a week, they saw that they could eliminate the air. After two months' operation, they found that they were using one one-sixth the amount of grease they had previously used. You can readily see that the life of the brasses will be greatly increased; and also danger of shut-downs due to hot bearings is practically eliminated.

I also hope that all mill machinery builders will take this paper to heart. Because they need it. In my 20 years' work in the lubricating equipment field, the machinery builders have lagged behind in realizing the importance of designing their bearings and moving parts so that the user can easily, safely and quickly lubricate these parts without shutting down the machine. And also provide enough lubricating points, and be sure and have only one point serve one bearing surface. They are guilty in being lax on this score. Just within the last 60 days, I saw a new machine in a finishing line, where one bearing beneath the machine, cannot possibly be lubricated without stopping the machine and a man crawling inside. This is a new type of machine, designed in the last 2 or 3 years, and yet you find this lubrication condition.

I also wish to emphasize that part of the paper that stresses the importance in the care of the lubricating equipment. The systems will do their work, but they require some inspection the same as any other machinery. And when any repairs are made on the mill machinery, be sure and see that the lubricating man is on the job to do his part in replacing the lubricating equipment. His presence there is just as important as any one of the millwrights.

MAURICE RESWICK: Mr. Phillips' excellent paper may be well adopted by plant lubrication engineers as a manual to guide them in their work. This paper lays down a number of cardinal rules, which are followed by illustrations from actual plant practice, calculated to hold operating and lubrication costs to a minimum. But holding costs down may at times be carried to extremes.

The practice of reconditioning turbine oil is rather questionable. The latest improved types of turbine oil now have an additive agent which minimizes oxidation, arrests the formation of acidity, and increases the stability of the oil. Selective filtration with Fuller's earth may remove this additive agent, and render the oil more susceptible to deterioration. In such oil filtration, there is usually a loss of about 30 per cent of the oil, and replacement with new oil is preferable on turbine applications.

R. A. BARTA: The reconditioning of turbine oil was merely an experiment, but the outcome based on the treated oil was quite satisfactory. This treatment is not practical where small volumes of oil are concerned.

C. E. S. EDDIE: I would like to refer to that part of the paper on the costs of lubrication. I wonder if the authors are in a position to give a composite cost in cents per ton for the entire plant. It is not necessary to include in that figure, the bearing cost, but only the purchased lubricant cost, or a composite cost per ton for the plant in general.

C. W. PHILLIPS: That is 2.8 cents, two cents and eight mills per gross ton of ingots produced. The total dollars used were in the operation of four blast furnaces, power house, 204 coke ovens, by-product and benzol, two pig machines, sinter plant, 14 open hearth furnaces, 44 in. and 32 in. mills, 18 in. sheet bar and billet mills, 10 in. and 12 in. merchant mills, docks, and all transportation equipment.

HERMAN BERRY: The paper just presented outlines a most interesting and worthwhile phase of modern steel production, and the authors are to be complimented for their frank treatment of the various subjects. It can be said that lubrication has always had a fundamentally important relationship to maintenance. However, until recent years many of the economic aspects of this relationship have not been sufficiently recognized. Even today some of the vital issues of this phase of maintenance are still overshadowed, unfortunately, by traditional operating methods.

The authors' statement that "the personal attitude involved in maintaining lubrication means as much as installing automatic lubricating systems," brings out a very interesting topic. Our experience shows that the personal attitude of all those connected with lubrication in any way whatsoever means very much more than installing automatic systems, for without the proper personal attitude the mere installation of some automatic device to replace hand methods of lubrication by no means solves the problem. In fact, the attitude of departmental heads, foremen, millwrights and oilers toward such devices may often be the determining factor in causing the automatic systems to either function properly or to be totally unsuccessful.

The selection of oilers is important in promoting good personal attitudes. Oilers should be selected on the basis of their mechanical knowledge of and interest in operating machinery. They should be thoroughly instructed as to their duty and their responsibility in protecting valuable equipment.

Another important phase of lubrication is the super-

vision of departmental oil houses. These should be in charge of a competent person who has a thorough knowledge of his entire mill. He should be familiar with all the lubricants used and the approximate amounts of each required for every piece of equipment under his jurisdiction. In the course of a good operating year some individual departments will use as much as $25,000.00 worth of lubricants, and this expenditure certainly warrants intelligent supervision.

The authors appropriately outline the importance which should be placed upon lubrication by the designing engineer. The lubrication engineer should be called in for recommendations during the process of every design, and his approval of the finished drawings should be as essential as that of the chief designing engineer.

All of us know of cases where machinery has been designed, constructed and installed, and then the lubrication engineer called upon to recommend the lubricant to be used. This condition makes it impossible to recommend the proper lubricant due to the design of the equipment, thereby, in some instances, necessitating the use of an inferior lubricant. Such practices have caused contamination of the lubricant and dirty conditions on and around the new equipment after only a few hours of operation.

D. N. Evans. Getting back to the 12 to 5 ratio we heard earlier, our mill uses a great deal more than 12 oils and 5 greases. We use at least five different greases on valves alone and I would say in our strip mill we use possibly thirty-five different lubricants. Of course that includes all of our auxiliaries. On the mill itself, probably just the roller line, we could get by with twelve oils and five greases.

The cost of the particular mill citied by Mr. Phillips is considerably lower than in our plant. It seems to me that "lubricating costs" are a result of the style of bookkeeping used. We figure ours on cost per ton of products shipped. Some plants figure their costs on ingot tonnage, others include processing oils, rags, waste, etc. Consequently the costs in the various plants are difficult to compare directly.

C. R. Hand: This paper has set forth many points for the thoughtful consideration of the administration of our steel plants. Lubrication engineers know all of these statements can be applied to their own experiences.

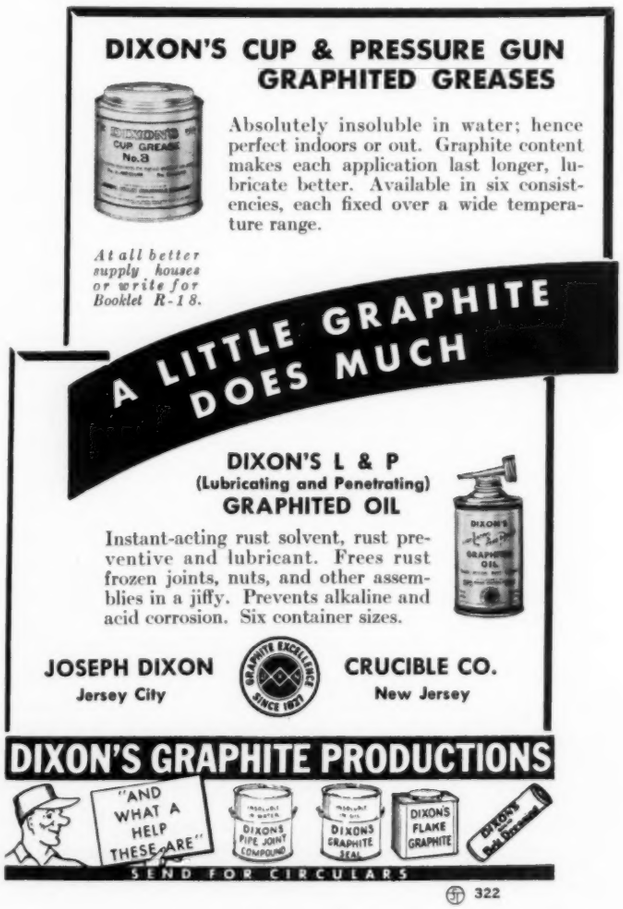
Quoting from the paper, "Too often we get machinery where the designer applies some sort of grease fitting or cup at the points of lubrication and lets it go at that." To this can be added, "Too often the designers refuse to submit drawings for approval before proceeding with the actual construction." This means that the purchaser can correct those maldesigns after he gets the machine.

In the case of multiple holes from the same line many references have been made to the fallacy of getting good service from more than one feed. Sheave pins are now almost always drilled with separate hole to each sheave bearing. On open hearth pit cranes, this may mean 10 holes in each pin.

Our experience shows that the machinery manufacturers are seldom qualified to install centralized lubrication systems. We have had several units delivered to us which required removing the entire system and installing it in the proper manner. Many times the manufacturer gets an order which merely states centralized system with no other qualifications. All orders should indicate as clearly as possible which system and how it should be installed. In most cases, the best way is to install lubrication systems after the machinery has been set on its foundation.

There are certainly many modern oil systems with too many gadgets. Many of these are entirely off the system within a short period after the unit begins operation. A well designed oil system properly attended by interested men does not require such elaborate attachments.

It is almost impossible to adhere to the specifications for lubricants which accompany the machinery delivered by some manufacturers. Names of oils and greases change. One will call for XYZ grease from some company, others will specify ABC from another. The lubricating engineer knows from experience what must be used. Manufacturers should have those who write their lubrication requirements, specify SAE standards so that those who are not lubricating engineers may know what to use. The personal attitude of those concerned with lubrication, is of utmost importance. Unless those in charge encourage the men and help them correct bad conditions as they are found, costs will continue to rise. When oilers' duties are divided between oiling and millwright helper, lubrication suffers. When the oiler is away, he cannot be held responsible for dry or hot bearings. Good oilers can save many dollars in the mill.


DIXON'S CUP & PRESSURE GUN GRAPHITED GREASES
DIXON'S CUP GREASE No. 3
Absolutely insoluble in water; hence perfect indoors or out. Graphite content makes each application last longer, lubricate better. Available in six consistencies, each fixed over a wide temperature range.
At all better supply houses or write for Booklet R-18.
A LITTLE GRAPHITE DOES MUCH
DIXON'S L & P
(Lubricating and Penetrating)
GRAPHITED OIL
Instant-acting rust solvent, rust preventive and lubricant. Frees rust frozen joints, nuts, and other assemblies in a jiffy. Prevents alkaline and acid corrosion. Six container sizes.
JOSEPH DIXON CRUCIBLE CO.
Jersey City New Jersey
GRAPHITE EXCELLENCE SINCE 1827
DIXON'S GRAPHITE PRODUCTIONS
"AND WHAT A HELP THESE ARE"
DIXONS PIPE JOINT COMPOUND
DIXONS GRAPHITE SEAL
DIXONS FLAKE GRAPHITE
SEND FOR CIRCULARS
322

ENGINEERING FIRM EXPANDS INTERESTS

▲ Negotiations have been concluded whereby The Wean Engineering Company, Inc., of Warren, Ohio, has purchased a controlling interest in The Broden Construction Company, Cleveland, Ohio, designers and manufacturers of wire and strip mill machinery.

This company will be operated as a subsidiary corporation of The Wean Engineering Company, Inc., who specialize in the design and manufacture of processing and annealing equipment for sheet, tin and strip mills.

A building expansion program is under consideration to take care of additional machinery requirements as well as steel fabricated air raid shelters.

Other associate companies of The Wean Engineering Company, Inc., are The McKay Machine Company, Youngstown, Ohio; Flinn and Dreffein Company, Chicago, Illinois; Lee Wilson Engineering Company, Cleveland, Ohio; The Hallden Machine Company, Thomaston, Connecticut; Wellman-Smith Owen Engineering Corporation, Ltd., London, England; and The Wean Engineering Company of Canada, Ltd., Hamilton, Canada.

The new officers of The Broden Construction Company are: R. J. Wean, president and treasurer; F. J. Keller, vice president and general manager; S. R. Wean, secretary; and N. L. Fromberg, assistant secretary. The new directors of The Broden Construction Company are: R. J. Wean, F. J. Keller, S. R. Wean, E. J. Boyd, and H. W. Lynn.

View of the plant of the Broden Construction Company, recently affiliated with the Wean Engineering Company.

ANNOUNCES PORTABLE ACETYLENE GENERATOR

▲ A new portable acetylene generator for use in oxy-acetylene welding and cutting has just been announced by The Linde Air Products Company, a unit of Union Carbide and Carbon Corporation. This generator, known as the Oxweld MP-10, will deliver 30 cu. ft. of acetylene per hr. and is suitable for welding metal up to $\frac{3}{8}$ in. thick, and for cutting steel up to 5 in. thick. It is designed for maximum portability, from a standpoint of weight and height, and can readily be moved about the shop or away from the shop for outside jobs. The generator can be recharged speedily, and is simple and easy to operate.

Generation of acetylene is started, set for regular operation, and stopped, by rotating the single pair of operating handles at the top of the generator. Once the operating handles have been set, generation of acetylene pro-

This portable generator has a capacity of 30 cu. ft. of acetylene per hour and weighs only 250 lb. when charged.

ceeds automatically. The pressure of acetylene delivered to the blowpipe is controlled by a regulator which forms an integral part of the generator, and a separate pressure gauge indicates at all times the pressure within the generating chamber.

Other construction features of the MP-10 generator include two relief valves which automatically vent any excessive pressures that should develop within the generator or in the delivery hose, and a hydraulic backpressure valve which, by providing a water seal between the hose and generator, prevents any reverse flow of gas.

The carbide hopper, which holds 15 lb. of 14 ND Union Carbide, is designed for easy recharging. It is first removed by the operator and hung from one of the water-shell handles for this operation. A turn of the wrist then removes the valve insert from the hopper, permitting insertion of the carbide funnel. This speeds recharging, and makes it easy to keep the feed valve clean and uncaked. This feed valve is of all-metal construction, and under normal usage should never require adjustment or replacement of parts. A revolving agitator blade at the bottom of the generator facilitates the removal of residue from the generating chamber during recharging.

The MP-10 is strongly constructed of welded steel parts. It weighs only 100 lb. when empty and 250 lb. when charged, and measures only 3 ft. 2½ in. in height.

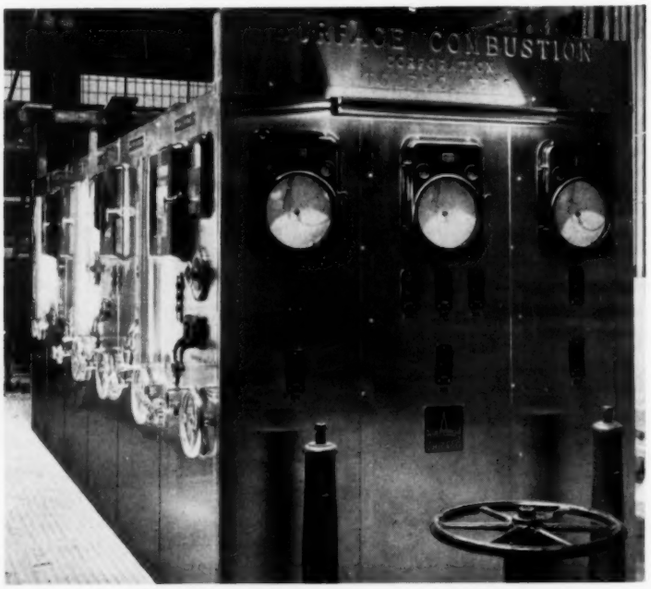
WIRE CAPACITY TO BE EXPANDED

▲ Plans for rehabilitation, consolidation and expansion of its facilities for the manufacture of rods, wire and wire products in the company's plants at Joliet and Waukegan, Illinois, were announced by C. F. Hood, president of American Steel and Wire Company, United States Steel Corporation subsidiary.

The program includes the construction of a new coarse rod mill and a new mill for the manufacture of merchant products at the Collins Street plant in Joliet, which, upon completion, will replace the present facilities at the Rockdale and Scott Street plants in the same city.

The new rod mill at Joliet will be adjacent to the present rod mills and eventually will replace the existing Waukegan rod mills. Present billet storage and shipping facilities will be enlarged to accommodate the new mill. Rod production thus will be increased somewhat by the installation. While the wire drawing capacity of the Joliet plant will not be greatly enlarged, the new facilities will permit increased production and an improved product for the merchant trade. Heat treating equipment for both rods and wire is included in the new mill. The new buildings at Joliet will include a structure with a total length of 480 ft. and a width of 150 ft. on one end and 80 ft. on the other to house the rod mill, together with a new conveyor building 30 ft. by 730 ft. The wire mill will have approximate dimensions of 960 ft. by 1500 ft. Total new floor space involved in the Joliet project will amount to over 1,100,000 sq. ft.

At Waukegan, replacements, rearrangement and improvements will be made to increase the efficiency of the mill and make it one of the most efficient units for the production of manufacturers' wire in the country.



If you could stand here

FORTUNATELY for Askania equipment, the steel industry is guided by men in whom the recognition of quality in mechanical equipment is instinctive—a sort of extra sense, born in them and sharpened up by practical experience.

Fact is, you are one of them yourself . . . and so we wish you could stand in front of this handsome, stainless steel panel board that houses the Askania Control of two 4-zone oil—or gas—fired slab heating furnaces.

You would see the signs you know so well—of sound basics interpreted in masterful design and carried out in precision workmanship. You would watch Askania Regulators hold fuel-air ratio, furnace pressure, and gas pressure to almost unbelievably close limits. You would see too, how easy the change-over from gas to oil is made. The fuel diaphragm of the ratio regulator is suitable for either fuel impulse. This is just one more of the many innovations pioneered by Askania.

That one experience would be your final reason for placing *every* automatic control problem in the hands of Askania Engineers!

ASKANIA REGULATOR CO., 1603 S. Michigan Ave., Chicago, Ill.

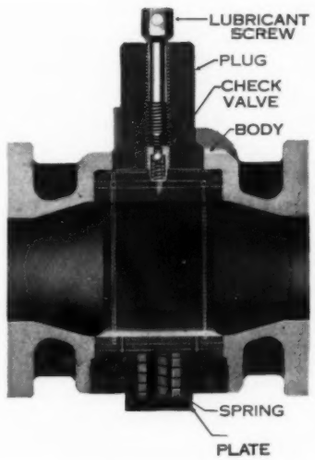
ASKANIA CONTROL

"IF IT CAN BE MEASURED—WE CAN CONTROL IT"

The Waukegan program includes provision for adequate rod storage, replacement and relocation of rod patenting equipment, replacement of heat treating equipment, replacement and relocation of straightening and cutting and tinning equipment, additional continuous wire drawing and finishing equipment, improvements and replacements in the spring mill to afford better arrangement and versatility in manufacture, replacement of cleaning house and of iron sulphate facilities, extension to warehouse space, and an addition to the present office building.

PLUG VALVE OFFERS VARIOUS ADVANTAGES

▲ The lubricated plug valve as manufactured by the American Car and Foundry Company has found wide application to many of the new wide strip mills put into operation over the past few years. These valves are perferred by both designers and operating personnel, due to their ease of operation and full area. This valve is a departure from the conventional type of lubricated plug valve, in that



it is constructed with a cylindrical plug as contrasted with a tapered plug. With this construction, the company has overcome two of the outstanding objections to a plug type valve, *i.e.*, possibility of hard turning and restricted area. The lubricated plug valve offers full unrestricted pipe area and the cylindrical plug also overcomes any possibility of sticking which might be due to the wedge effect of a taper. This valve also has the advantage of compact construction; being lubricant packed, it does not require the conventional type stuffing box nor any auxiliary packing. For replacement work the 125 lb. pressure valve has standard gate valve face to face dimension. As contrasted with a gate valve, the lubricated plug valve is quick operating and has an extremely long life since it does not have any seating elements exposed to the wear of the lading. Another very commendable feature incorporated in the valve is the lubricant release, by means of which lubricant is prevented from entering the line; this is accomplished by means of a visible exuding of excess lubricant at the neck of the valve in case an overcharge is forced into it. The valve can be secured in wrench operated types up to 12 in. and in gear operated types up to 16 in., all having full area. Venturi types are available in sizes from 6 to 24 in., the larger sizes being either spur or worm gear operated. Three and four way valves

TRADE AUTOMATIC MARK

MANUFACTURERS FOR OVER THIRTY YEARS

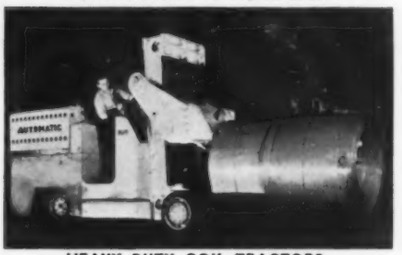
MODERN *Electric Propelled* INDUSTRIAL TRUCKS

FOR ECONOMICAL MATERIALS HANDLING

- COIL AND FORK TRACTORS
- SHEET AND TIN PLATE HANDLERS
- BOSH TRUCKS
- LOW AND HIGH LIFT TRUCKS
- LOAD CARRIERS
- TRACTORS — CRANES

COIL TRACTORS
Capacities 8,000 to 18,000 Lbs.

BOSH TRUCKS—*Tiering Type*



HEAVY DUTY COIL TRACTORS
Capacities Up to 30,000 Lbs.

FORK TRUCKS
Telescopic and Non-Telescopic Lifts
For Sheet Coils and Pallet Handling
Capacities 3,000 to 7,000 Lbs.

SHEET AND TIN PLATE HANDLERS
Capacities 8,000 to 18,000 Lbs.—Non-Telescopic and Telescopic Lifts

REQUEST DETAILS AND LITERATURE

Listed Under Reexamination Service of UNDERWRITERS' LABORATORIES

AUTOMATIC TRANSPORTATION CO.
47 W. 87th St. Div. of the Yale & Towne Mfg. Co. CHICAGO, ILL.

are also standard as well as a full round port type. Steam jacketed valves can be supplied for services requiring a heated valve.

These plug valves are in service in the modern strip mill handling gas to slab heaters, annealing furnaces and normalizing furnaces, such as manufactured by Amsler-Morton Company, Salem Engineering Company, C. M. Kemp Manufacturing Company, Rust Furnace Co., and Surface Combustion Corporation; you will also find them in the pickling department handling acids. In mills that are equipped with coke ovens you will find these valves being used as reversing valves on coke ovens as well as for main line valves handling coke oven gas. The valve is recommended by the American Car and Foundry Company for general plant service in all processing industries for handling such services as gasoline, oil, hot and cold water, compressed air, caustics, acids, steam, asphalts and many other fluids. Requests for catalogs and price information can be addressed to the American Car and Foundry Company, Valve Department, 30 Church Street, New York, New York.

STEEL CORPORATION ACQUIRES PROPERTIES

▲ The tin plate manufacturing plant of Standard Tin Plate Company and the coal mining properties of Canonsburg Coal Company, subsidiaries of Continental Can Company, were acquired by Carnegie-Illinois Steel Corporation, a United States Steel subsidiary, on July 1, to supplement the tin plate manufacturing facilities of Carnegie-Illinois in meeting the heavy demands upon it in the present emergency.

On that date, the former employees of the tin plate and coal companies, about 2000 in number, became employees of Carnegie-Illinois.

REPUBLIC TO INSTALL TWO MORE ELECTRICS

▲ The nation's supply of all-important electric furnace steel will be increased by at least 122,000 tons annually with the completion of two electric furnaces ordered by Republic Steel Corporation. The furnaces will be installed in Canton.

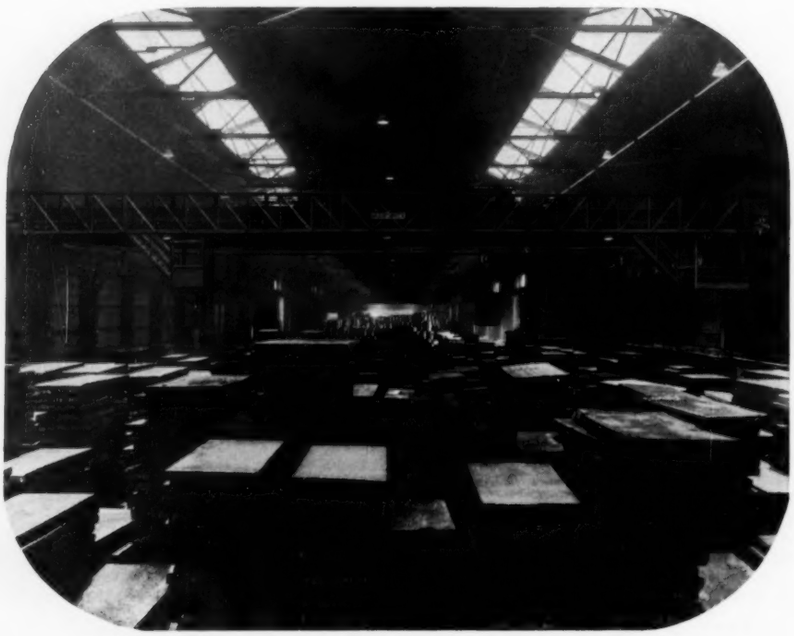
Already the largest producer of electric furnace steel in the United States, the two 50-ton furnaces will increase the corporation's present capacity of 605,000 tons annually to 727,000 tons, as compared to 146,000 tons at the beginning of 1940.

During 1940 Republic installed six 50-ton electric furnaces to meet the constantly increasing demand for this special type steel. Electric furnace steel is vital in the manufacture, among other things, of aircraft motors and light armor plate.

The output of the new furnaces will be used substantially at this time for these purposes.

Delivery of the furnaces is expected about October 15, and it is expected that they will be in operation by approximately November 1.

Also a new unit for the increased production of steel plate is to be started immediately at the 98-in. strip mill.



120'-0" Span Cleveland All-Welded Magnet-Handling Crane

IN MODERN MILLS IT'S CLEVELAND ALL-WELDED CRANES

Large numbers of Cleveland all-welded cranes are serving the outstanding mills built in recent years.

Because Clevelands keep going smoothly and solidly even after years of hard service, they rank high with steel-mill engineers.

When low maintenance costs and extra years of service built into Clevelands are considered, it is easy to see why they are an unusually good investment.

THE CLEVELAND CRANE & ENGINEERING CO.
Wickliffe, Ohio

CLEVELAND CRANES
ALL-WELDED OVERHEAD TRAVELING CRANES
Other products: CLEVELAND TRAMRAIL and STEELWELD MACHINERY

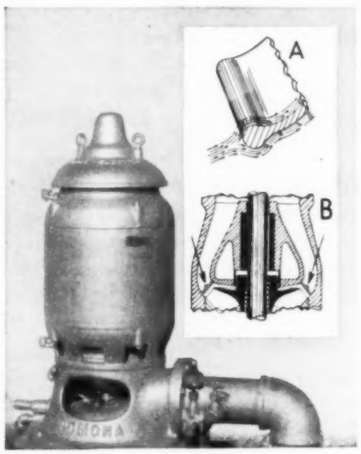
The addition, a building 700 ft. long by 75 ft. wide, will house equipment which will more than double Republic's Cleveland production of this vital defense material.

It is being used in constantly increasing quantities in the construction of ships and railroad cars, both of utmost importance to the defense program.

The company is now producing approximately 380,000 tons a year, of which 180,000 is produced in Cleveland and 200,000 tons in other plants of the company. The new equipment will increase the total output of the corporation to 600,000 tons annually.

NEW DESIGN RAISES PUMP EFFICIENCY

▲ The Pomona Pump Company, St. Louis, Missouri, and Pomona, California, has recently been granted patents covering design improvements which eliminate hydraulic losses in pumps, thereby increasing efficiency as much as 10 per cent. These improvements, now included in all sizes



of Pomona vertical turbine pumps, involve fundamental design changes in the guide vanes, function of which is to alter, from horizontal to vertical, the flow direction of fluids being pumped.

Previous practice in pump manufacture dictated that these guide vanes can be constructed as thin as possible on the advance edge, on the theory that the less metal the fluid would strike, the less would be the resistance encountered. However, it was discovered by Pomona engineers that, because fluid being discharged by the impeller element flows across the guide vanes at various angles (instead of always directly across the advance edge), eddy-friction losses are encountered, reducing the efficiency of the pump.

By forming these advanced vane ends of a bulbous shape, it was discovered that regardless of the flow direction of the fluid, its direction would always be substantially tangential to the vane surface. Thus, greater uniformity of flow pattern is secured, friction is reduced and efficiency of fluid lift is increased. Furthermore, because of the recessive curve at the rear of the bulb-shaped vane, eddy currents are not developed as under former circumstances.

The improvement is inherent in the pump design, so that there are no gadgets or small parts to wear out. The new vane shape increases overall operating efficiency as much as 10 per cent, with no increase in the original investment, and in addition permits the high efficiency to be maintained over a broader range of capacities than

CROUSE-HINDS

A few of the many explosion-proof Condulets that meet usual and unusual electrical conduit requirements.

- Created by our engineers
- Manufactured in our plant

CONDULET
Type EJH Junction Condulet
Type EMS Mercury Switch Condulet
Type OFC Push Button Station Condulet
Type EMH Instrument Condulet
Type EPH Pothead Condulet
Type ETB Telephone Condulet
Type EPC Interlocking Plug Receptacle and Circuit Breaker Condulet
Type GUB Instrument Condulet
Type FSQ Interlocked Receptacle and Switch Condulet
Type TCH Electric Clock Condulet
Type HRC Thermostat Condulet

A Nationwide Distribution Through Electrical Wholesalers

CROUSE-HINDS COMPANY
SYRACUSE, N. Y., U. S. A.

Sales Offices: Birmingham — Boston — Chicago — Cincinnati — Cleveland — Dallas — Detroit — Houston — Kansas City — Los Angeles — Milwaukee — Minneapolis — New York — Philadelphia — Pittsburgh — San Francisco — Seattle — St. Louis — Washington

Resident Salesmen: Albany — Atlanta — Baltimore — Buffalo — Charlotte — Denver — Louisville — New Orleans

CROUSE-HINDS COMPANY OF CANADA, LTD., Main Office and Plant: TORONTO, ONT.

CH703

is possible with ordinary turbine pumps. Moreover the broader guide vanes give increased strength because of their extra thickness.

Inasmuch as the new guide vanes are an inherent part of the pump bowl assembly, it is not necessary for the owner of a vertical turbine pump to purchase a complete new pump in order to take advantage of the new design. It is only necessary to substitute a new bowl assembly. The manufacturer will be pleased to supply explanatory literature upon request.

PLANTS TO INSTALL NEW SOAKING PITS

▲ To assure adequate steel capacity and to take advantage of the latest improvements in soaking pit design, many mills are placing orders for new pits. Indicative of the trend are the following orders recently received by Surface Combustion Corporation of Toledo, Ohio, for one-way fired pits:

Jones and Laughlin Steel Corporation is purchasing fifteen holes. Five of these holes will be installed at the Aliquippa plant. Each hole will have dimensions of 7 ft. wide by 18 ft. long and will be heated by a mixture of blast furnace and coke oven gas. Two five-hole batteries will be installed at the South Side works. These holes will have dimensions of 7 ft. 2 in. wide by 16 ft. 6 in. long and will be heated with coke oven gas. All fifteen holes will be equipped with automatic program heating control and individually operated covers.

Sharon Steel Company is installing five holes. These will be oil fired, each hole having dimensions of 6 ft. 8 in. wide by 23 ft. 6 in. long.

Republic Steel Corporation is installing five holes. These pits are now being placed in operation at Canton, Ohio, for alloy ingots. They are heated with natural gas.

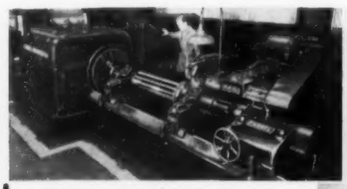
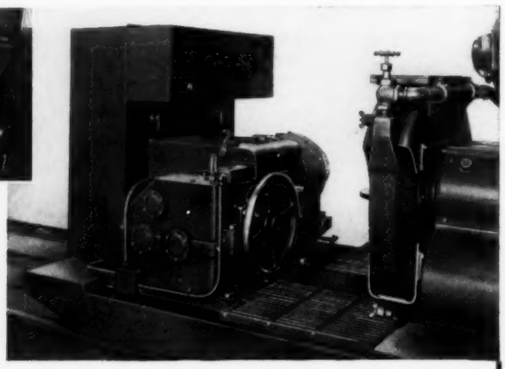
American Rolling Mill Company purchased five holes. These are in addition to the five holes placed in operation last year.

All of the above pits will be equipped with completely automatic control of temperature, pressure, and atmosphere. They represent an investment of more than $1,000,000.00.

NEW BREAKERS OFFER CIRCUIT PROTECTION

▲ To meet present demands for safe, automatic protection of lighting and power circuits, the Colt's Patent Fire Arms Manufacturing Company announces the addition of types M1 and M2 industrial multi-breakers to their complete multi-breaker line. Having the advantage of a lower price range, these devices can be supplied with either two or three poles and in ampere ratings from 15 to 100, for 230 volts a-c. systems only. Type M1 indicates ampere ratings of 15 to 50; type M2 ampere ratings of 50 to 100.

The Colt industrial multi-breakers provide automatic protection against short circuits and overloads . . . and permit resumption of service by a simple movement of the operating handle after cause of interruption has been removed. It is not necessary to replace parts within the breakers and thus maintenance costs are minimized. Common trip is provided as-

Smooth Vibrationless Carriage Traverse Assures Roll Accuracy and Fine Finish in

FARREL ROLL GRINDERS

A feature of the Farrel Heavy Duty Roll Grinder which contributes greatly to a continuous high output of rolls ground to uniform accuracy and fine finish is the smooth, positive traverse, steadiness of travel and the smoothly accurate reverse of the carriage carrying the grinding wheel.

Vibrationless traverse is achieved by driving the carriage by a reversing motor through accurately generated Farrel-Sykes continuous tooth herringbone gears and a worm reduction to a worm meshing with the rack on the bed. This is the smoothest type of mechanical drive known for machine tool carriages.

Reversal is accomplished electrically, eliminating mechanical clutches. A variable speed motor and a two-speed drive provide a wide, adjustable speed range for every grinding condition. Speed change and point of reversal are quickly and easily set at the operator's station. They are automatic and require no attention by the operator except adjustment to changing conditions as the work progresses.

Our Bulletin No. 111 describes this and the many other important features which contribute to the high output and superior performance of Farrel Heavy Duty Roll Grinders. We shall be glad to send a copy promptly on request, without obligation.

FARREL

FARREL-BIRMINGHAM COMPANY, Inc.
ANSONIA, CONN.
New York • Buffalo • Pittsburgh • Akron • Chicago • Los Angeles

At this mammoth works of Aluminum Company of America, expanded fivefold since hostilities began between Great Britain and Germany, tubing is being produced on a 20-shift-a-week basis for use in aircraft, naval vessels, signal equipment and other defense needs of the government. Production capacity will by the end of this year be nine times greater than at the start of the war.

ALUMINUM CAPACITY TO BE INCREASED

▲ The expansions at the plants in Los Angeles, California, and Lafayette, Indiana, of the Aluminum Company of America are rapidly nearing completion.

In 1937, in order to serve the airplane industry more effectively, the company bought 15 acres of land in Vernon, a section of Los Angeles, and erected on it a sand and permanent-mold foundry and forge plant. The works was completed early in 1938. At the start of the war, the Vernon works had a capacity of 100,000 lb. of aluminum alloy forgings, and 424,000 lb. of sand and permanent-mold castings a month.

In the spring of 1940, an expansion of the facilities in Vernon was announced. This expansion included the addition of an extrusion works and a rivet plant, as well as additions and betterments to the existing aluminum foundry and forge plant. To carry on this expansion, the company acquired an adjacent 30 acres of land.

The buildings necessary to house the additional fabricating facilities in Los Angeles have now been completed and the equipment is rapidly being installed to handle the increased production, so that very shortly the sand and permanent-mold casting capacity will have been increased to 593,000 lb. a month (an increase of 40 per cent), and the forging capacity to 450,000 lb. a month (an increase of 350 per cent); while the new extrusion plant will be turning out extruded shapes at the rate of 1,019,000 lb. a month; and the new rivet plant, rivets at the rate of 70,000 lb. a month. By March 1942, the forging capacity of the Vernon works will have been increased an additional 50,000 lb. a month.

ALL THIS at a single glance

1. RATE OF AIR FLOW
2. RATE OF FUEL FLOW
3. RATIO OF AIR TO FUEL OR PERCENTAGE OF AIR EXCESS OR DEFICIENCY

USED on multiple zone slab heating furnaces, for instance, to secure maximum heating rate and efficiency of fuel consumption at the same time making possible the control of the furnace atmosphere to be oxiding (excess of air) or reducing (deficiency of air) as dictated by the requirements.

Many other uses in steel mills, gas producing plants, heat generating plants, CO_2 generating plants, sewage plants, chemical plants, kilns, air conditioning—any place where there exists a relation between any two of the following functions: flow of gas or flow of oil or other measurable fluids; pressure, draft, suction, temperature (up to 1000°F.) speed in r.p.m. or inches per minute, position, level and others.

The cross-pointer feature offers an ingenious method of revealing relationships not apparent in separate instruments or conventional scales. This distinct innovation is found only in Hays Visio Ratio Gage.

If you will write us, stating the condition, we will tell you exactly how the Hays Visio Ratio Gage can be applied to your problem.

Address us . . . .
955 Eighth Avenue,
Michigan City, Ind.

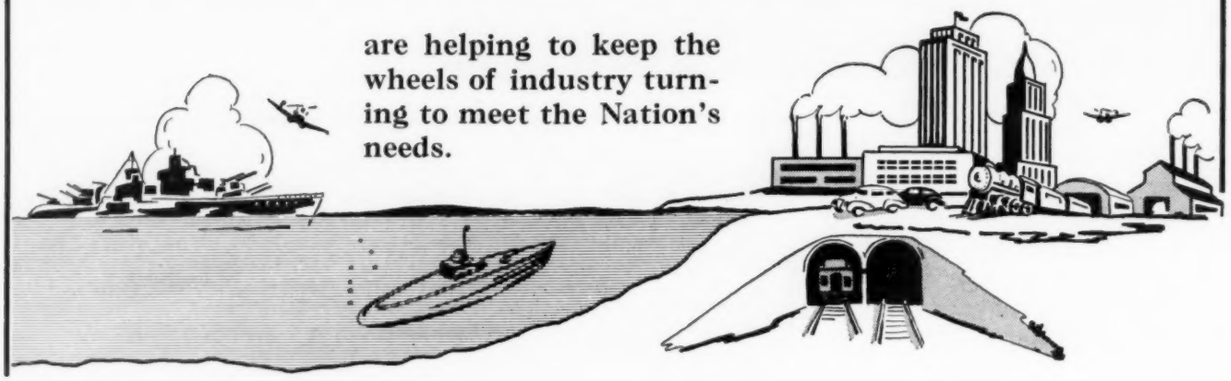
The HAYS CORPORATION
SINCE 1901 COMBUSTION INSTRUMENTS AND CONTROL
MICHIGAN CITY, INDIANA, U.S.A.

ADVERTISING PAGES REMOVED

Afloat and Ashore . . . Aloft and Below

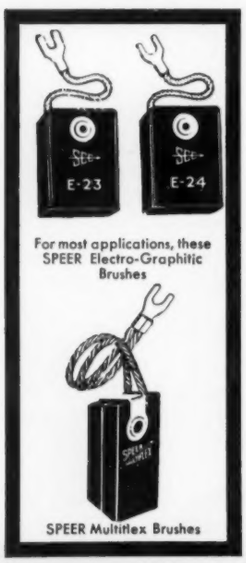
SPEER MOTOR AND GENERATOR BRUSHES

are helping to keep the wheels of industry turning to meet the Nation's needs.



CHOOSE SPEER BRUSHES

Choose SPEER brushes for your own motors, generators and rotaries—for better commutation, for longer brush life, for greater efficiency, for continuity of operation.



SPEER brushes—result of more than four decades of specialization, research, and constant development—are available in a wide variety of grades to meet the requirements of electrical equipment, new and old. In addition, SPEER electrical engineering specialists in commutation are always available for consultation and advice.

SPEER CARBON CO.
ST. MARYS, PA.

SCC

B—145

FOR *Safetys'* SAKE

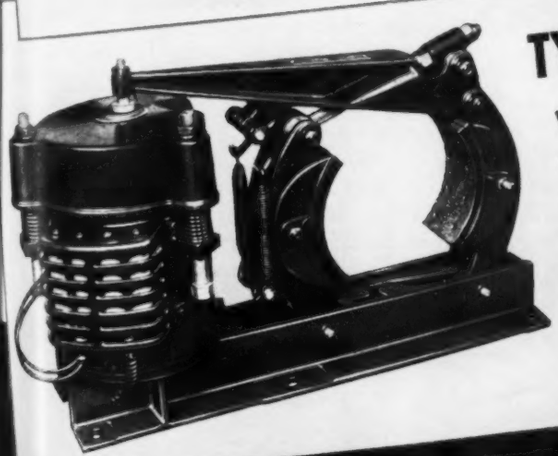
EQUIP YOUR OVERHEAD CRANES WITH

WAGNER

HYDRAULIC BRIDGE BRAKES

TYPE H

Wagner Hydraulically Actuated Bridge-Brake For Inside Cranes.



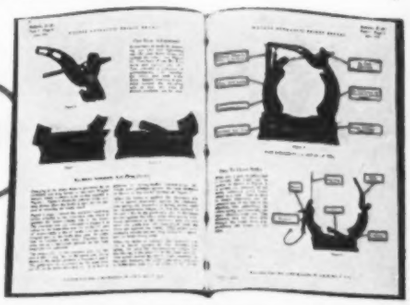
TYPE HM

Wagner Hydraulic Bridge-Brake with automatic parking attachment for Outside Cranes.

With production stepped up and everything moving at top speed it is best to be sure of your overhead crane-brakes. Be sure of quick, smooth, safe stops at all times by equipping all your cranes with Wagner Hydraulic Bridge-Brakes.

Wagner Hydraulic Bridge-Brakes employ the same dependable hydraulic actuation used on passenger cars and commercial vehicles. There are two types — type H (hydraulically-actuated crane bridge-brake), and type HM (a hydraulic bridge-brake with automatic parking attachment). Both types incorporate features found in no other bridge brakes.

SEND FOR BULLETIN IU-20



This bulletin gives you complete information on Wagner Bridge-Brakes and should be in the hands of all production, safety, and maintenance superintendents. Write for your copy today.

141-2

Wagner Electric Corporation

6400 Plymouth Avenue, Saint Louis, Mo., U.S.A.

TRANSFORMERS • MOTORS • FANS • BRAKES

NEW LITERATURE

▲ So that everyone interested in carburizing can become familiar with a method, now used in many heat-treats, which is said to put a case of just the specified thickness on a variety of work . . . gears, spindles, bearing-cones, bushings, camshafts, etc. . . . the Leeds and Northrup Company has just issued a 28-page catalog . . . "Homocarb Method for Carburizing."

Different from most carburizing publications, this book takes the reader on a pictorial tour of representative heat-treats . . . shows a score of furnaces in action . . . shows the various types of work being carburized . . . and even tells how results are obtained.

In addition to many action photos, there are diagrams, charts and photomicrographs which demonstrate how and why the Homocarb Method is said to enable a heat-treater to "get the case he wants."

Anyone who wants a copy of this publication may have it by addressing the Leeds and Northrup Company, 4934 Stenton Avenue, Philadelphia, Pennsylvania, and asking for Catalog T-623 . . . "Homocarb Method for Carburizing."

▲ Holophane Company, Inc., 342 Madison Avenue, New York, announces the availability of a 16 page bulletin describing Controlenses for fluorescent lamps. This book describes the three Controlenses with different light distribution characteristics which will solve the majority of lighting problems and enable the user to obtain the maximum advantage of the lamp. This book also describes the optical performance of each, lists their advantages, shows how results can be predicted and describes and illustrates equipment using them.

▲ Thompson Electric Company, 1101 Power Avenue, Cleveland, announces a new 44 page catalog. This book goes into quite a bit of detail illustrating with diagrams and photographs typical installations in all industries. Copies of this catalog may be had by addressing the manufacturer.

▲ A new bulletin (B-6142) available from Allis-Chalmers Manufacturing Company, Milwaukee, Wisconsin, is on metal-enclosed outdoor switch houses for feeder or line protective switching equipment. Profusely illustrated, it gives construction features, application data, dimensions and typical design arrangements.

▲ The Brown Instrument Company, Philadelphia, Pennsylvania, has just issued a new bulletin entitled "Brown Hot Blast Control System."

This new bulletin fully describes the Brown hot blast temperature control system which has proved itself to have great operating value in controlling the manufacture of pig iron in a blast furnace. It is a rugged, responsive system allowing furnace operators to control more easily and within much closer limits the conditions in the blast furnace. It tells operators by means of howlers, signals and other alarms, when it is necessary to change stoves or to readjust, manually, air through the stove. Once a stove has been cut in, the system immediately adjusts the cold blast mixing valve and holds the blast temperature at exactly the desired value.

OVERHEATED WORKMEN

Cost you more than

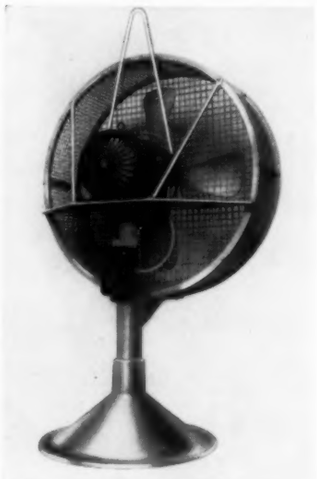
TRUFLO FANS

TRUFLO CRANE CAB FANS
For cooling interiors of crane cabs and other confined areas. Adjustable both horizontally and vertically. Four blade type, 12 and 18 inch sizes.

Truflo Fans PAY OFF by making workmen cooler, more comfortable. The result is increased efficiency, more profits for you.

All Truflo Fans are constructed to give the utmost in service at minimum cost. One-piece aluminum alloy propellers supply MORE air per h.p. . . . perfectly-balanced blades assure longer motor life . . . extra strong frames stand up longer under hard use.

Many mills throughout the country have found that efficiency gained as a result of using Truflo Fans more than pays the cost. Put Truflo Fans on *your* payroll now!



TRUFLO PORTABLE COOLING FANS
Easily portable. Help keep efficiency high where work is hottest. 12 to 36 inch diameters.

PORTABLE COOLING FANS

CRANE CAB FANS • WALL FANS

EXHAUST FANS • BLOWERS

ROOF VENTILATING FANS

PENT HOUSE FANS

Write for Illustrated Literature

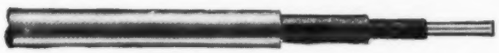
TRUFLO FAN COMPANY

554 MAIN ST., HARMONY, PA.

Rockbestos Wires Permanently Resist
HEAT-MOISTURE-OIL-GREASE-FIRE

These wires are but a few of the 118 different permanently insulated standard constructions developed by Rockbestos to withstand the destructive action of heat and moisture, oil, grease and corrosive fumes without drying out, cracking, rotting, swelling or failing. All of them are absolutely fireproof. File this page under "Wires for Severe Operating Conditions" and refer to it when you reach the wire-specifying stage of your planning. For complete information send for catalog.

Rockbestos Products Corporation, 805 Nicoll Street, New Haven, Connecticut



600 VOLT A.V.C. SWITCHBOARD WIRE — TABLE B
(Underwriters' Type AVB)

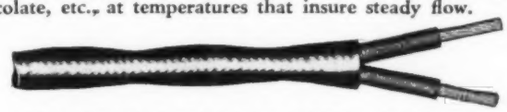
Sizes No. 18 to 4/0 A.W.G. with varnished cambric and felted asbestos insulation and gray, black, white or colored flameproof cotton braid.

Combine fire insurance and fine appearance in your switchboards with Rockbestos Switchboard Wire. It is absolutely fireproof and will not dry out under heat. Sharp, clean bends can be made without cracking as the asbestos wall acts as a cushion under the braid. Rockbestos A.V.C. Hinge Cable and Switchboard Bus Cable have the same fireproof and heatproof characteristics.

INDUSTRIAL HEATING CABLE — TABLE LH

No. 19 A.W.G. nickel-chromium wire insulated with .040" of felted asbestos and covered with 4/64" waterproof lead sheath.

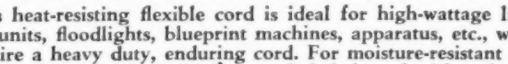
This pliable cable distributes a mild heat evenly over a large area. Prevents freezing of water pipes, wet pipe sprinkler systems, etc. Keeps conveyor pipes for fuel oil, soap, varnish, ink, chocolate, etc., at temperatures that insure steady flow.



ALL-ASBESTOS FLEXIBLE CORD — TABLE CA

Sizes No. 10 to 18 A.W.G. with two or three conductors insulated with felted asbestos, covered with asbestos braid. Also in A.V.C. (asbestos and varnished cambric) constructions.

This heat-resisting flexible cord is ideal for high-wattage lighting units, floodlights, blueprint machines, apparatus, etc., which require a heavy duty, enduring cord. For moisture-resistant construction specify the A.V.C. type. Labeled cord with polarized conductors if desired.



600 VOLT A.V.C. BOILER ROOM WIRE — TABLE C
(Underwriters' Type AVA)

Sizes No. 18 to 4/0 A.W.G. This construction for sizes 18 to 8, sizes 6 to 4/0, have another wall of felted asbestos next to the conductor.

For lighting and control circuits exposed to heat and moisture, oil, grease, corrosive fumes or fire hazard, such as exist around furnaces, ovens, lehrs, soaking pits, boilers, etc., this widely used A.V.C. construction is ideal. Also for locomotive panel wiring and for switchboards requiring an asbestos braided wire.

600 VOLT A.V.C. POWER CABLE — TABLE E
(Underwriters' Type AVA)

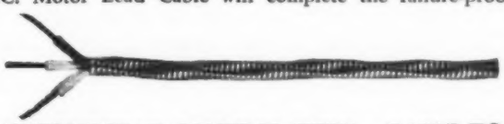
Sizes No. 18 A.W.G. to 1,000,000 CM insulated with laminated felted asbestos and varnished cambric, and asbestos braid. Other constructions for service voltages up to 8000.

This cable is recommended for power circuits and hot spot wiring in or around boiler rooms, ash pits, steam tunnels, soaking pits, tenter frames, glass plants, steel mills, etc. The asbestos and heat-sealed varnished cambric construction has ample moisture resistance and withstands high temperatures indefinitely.

ASBESTOS INSULATED MAGNET WIRE

Round, square and rectangular asbestos insulated conductors finished to meet varying winding conditions and coil treatment requirements.

Protect your motors against heat-induced breakdowns with class B windings of Rockbestos Heat-Resisting Magnet Wire. Leads of A.V.C. Motor Lead Cable will complete the failure-proofing.



THERMOSTAT CONTROL WIRE — TABLE TC

Sizes No. 14, 16 and 18 A.W.G. in two to six conductors with 12½, 25 or 32 mil wall of felted asbestos insulation and cadmium plated steel armor.

A multi-conductor control wire for low voltage intercommunicating, signal and temperature control systems. Its lifetime insulation and rugged steel armor will give you troubleproof circuits.

600 VOLT ALL-ASBESTOS RHEOSTAT CABLE—TABLE R
(Underwriters' Type AI)

Sizes No. 18 A.W.G. to 1,000,000 CM insulated with a heavy wall of felted asbestos, covered with a rugged asbestos braid finished in black, white or colors.

Use this power and rheostat cable for wiring rheostats, switchboards, elevator and locomotive control panels and electrical equipment exposed to heat, fumes and fire hazard. Also for general open wiring in dry, high temperature locations. For solid conductor specify Rockbestos Rheostat Wire, Table A.

600 VOLT A.V.C. MOTOR LEAD CABLE — TABLE L
(Underwriters' Type AVA)

Sizes No. 18 A.W.G. to 1,000,000 CM insulated with two walls of felted asbestos and a high-dielectric, heat-sealed varnished cambric insert, covered with heavy asbestos braid.

Heatproof, fireproof, greaseproof and oilproof, this cable will not dry out and crack, won't burn or carry flame, and will remain permanently flexible. For coil connections, motor and transformer leads where extreme heat and fire hazards are encountered as in steel mills, boiler rooms, etc.

600 VOLT A.V.C. CONTROL CABLE

In one to 19 conductors. Standard stranding A.W.G. No. 12 — 19/No. 25 and No. 9 — 19/No. 22. Other strandings furnished to order.

Designed for use under conditions too severe for control cables with other types of insulation which deteriorate rapidly when exposed to high temperatures. Operates without failure under the attack of heat, oil, grease or corrosive fumes and may be installed in conduit as it has ample moisture resistance.

Also refer to McGraw-Hill Electrical Buyers Reference

ROCKBESTOS — *the wire with permanent insulation*

Meet the Equipment Manufacturer

THE AMSLER-MORTON COMPANY

Herewith is presented the second in a series of articles outlining the history and development of the many companies servicing the iron and steel industry. It is felt the progress of the equipment manufacturer has been so closely allied with the upward march of the steel industry that our readers would be interested in the many developments sponsored by the manufacturer which were so helpful to the industry. In later issues this series will be continued.

▲ The Amsler-Morton Company, Inc., engineers and contractors, with main offices in Pittsburgh, Pennsylvania, is the successor of the Amsler Engineering Company which was founded in 1903 by Dr. Walter O. Amsler.

Early in its career the parent company engaged in general industrial engineering and construction—designing and building steel reinforced concrete buildings. Later, blast furnaces, hot blast stoves, open hearth furnaces, steel heating furnaces and glass melting furnaces were built. But by the end of its first decade, in 1913, there was a marked tendency to specialize in the field of combustion and fuels as applied to the steel and glass industries.

In 1914, William A. Morton entered the employ of the Amsler Engineering Company. At that time, the company was engaged principally in building and installing the Amsler gas producer, and in converting to producer gas many different types of steel and glass plant furnaces located in the existing natural gas fields which were then beginning to decline. It was not very long after joining the organization that Mr. Morton made his first important technical contribution to the business. This was in connection with the development of a muffled type raw producer gas-fired continuous annealing furnace, or lehr, for the glass industry. This lehr proved an outstandingly successful solution of a serious problem and helped to establish the company as a creative force in the useful application of heat. The industry accepted the lehr at once and more than 500 units were subsequently built for the glass industry alone. Other adaptations went into the enameling and pottery industries.

In 1916, the company was reorganized and the name changed to The Amsler-Morton Company with Dr. Amsler as president and Mr. Morton as vice-president.

Early in 1918, Paul L. Geer came into the organization as chief engineer after previous experience in the ceramic industry and with American Bridge Company and Carbon Steel Company. Although Mr. Geer, in those days, devoted his efforts primarily to the production end of the business, he was responsible for many improvements in the design and construction of furnaces and other equipment. It may be interesting to note, in passing, that Mr. Morton and Mr. Geer together have contributed to the company more than a hundred and fifty United States and foreign patents.

Dr. Amsler disposed of his interest in the company in 1922 and retired from active service. Mr. Morton then became president and Mr. Geer, secretary and treasurer. During the early twenties, some work was done for the steel industry. The glass industry, however, became the major field of the company's activities for the ensuing ten years or more. This

WILLIAM A. MORTON . . . (left)

Started with company in 1914 . . . became vice president in 1916 when company was reorganized under present name . . . has been president since 1922.

PAUL L. GEER . . .

Came into organization in 1918 as chief engineer . . . previously had been associated with American Bridge Company and Carbon Steel Company . . . has been secretary and treasurer since 1922.

The engineering department has recently been expanded to meet the demands of increased business activity.

can be attributed not only to the great demand for increased glass melting and annealing capacity to serve the rapidly developing high speed machine production of glassware, but also to innovations and improvements contributed by the AMCO organization.

The principal and most far reaching innovation of these years was Mr. Morton's invention of the AMCO high temperature refractory recuperator. This is an industrial heat exchanger to utilize the heat in the waste gases from a furnace for preheating the air required to support combustion in the furnace. This recuperator overcame the weaknesses of existing designs by eliminating all but horizontal joints, permitting the weight of the parts to seal the joints against leakage, and, by an understanding selection of materials, providing thin walled tubes of slip-cast, dense, highly-refractory clays which allow rapid heat transfer with low internal stresses. Further, the tubes through which the hot waste gases pass, being set vertically in the recuperator chamber, carry the heat equally rapidly to all parts of the assembly so that the cold air, passing counterflow in baffled circuitory passages around the tubes, picks up the heat without disturbing the thermal balance of the assembly as a whole. Waste gas temperatures up to 2900 degrees F. have been handled with resultant air temperatures up to 2200 degrees F.

The service rendered to industry by the AMCO recuperator can be compared with that of the Siemens regenerator which, it may be recalled, was first put into use by William Siemens, the inventor, on a glass melting furnace in 1861. But the regenerative system, with its two checker chambers, must be reversed periodically, which means that the ports of the furnace which it serves have to be utilized alternately both as firing and as waste gas ports. The recuperative system, however, is continuous in operation, eliminating the reversals and permitting the firing and waste gas ports of the furnace served to be designed and calibrated for one specific duty only. The importance of this advantage of the recuperative system is being demonstrated repeatedly in these modern days of automatic furnace controls.

Within the decade under consideration, the company built more than two hundred recuperative glass melting furnaces in this country and abroad. Fuel requirements of some of these furnaces were as much as 50 per cent lower than in direct fired practice. Economic conditions in Europe, where even the smaller countries were trying to develop local industries behind tariff walls and trade restricting regulations, called for comparatively small rather than large glass producing units. Further, fuel was relatively expensive. The AMCO recuperative design, with its double arched roof for the removal of waste products to the recuperator which is close coupled to the back of the melting chamber, gave the industry lower cost units which

PAUL M. OFFILL . . . (right)

Joined the company in 1926 as vice president . . . before he had been connected with M. K. & T. R. R., Laclede-Christy Clay Products Company, H. L. Dixon Company, and Simplex Engineering Company.

KARL W. GASS . . .

With company since 1935 as chief engineer . . . had enjoyed previous engineering experience with United Power and Pump Company; Chester and Fleming, Consulting Engineers; and Fort Pitt Engipneering Comany.

were as thermally efficient as the largest regenerative designs, and occupied comparatively small floor area per ton of glass produced.

Among the improvements contributed to the manufacture of glass during the twenties, one of the most interesting was the result of applying fundamental science with engineering skill to the cross-fired, reversing, regenerative melting furnace. This type of furnace had been employed for years to produce molten glass continuously. The design and construction of these furnaces, however, had remained more or less matters of tradition and rule of thumb. But, as the size of the furnaces was made larger, with greater outlay of capital, and anticipated increases in the production of acceptable glass did not materialize, many owners, searching for relief, accepted the ideas that AMCO had been suggesting. The nature of these changes and the ideas back of them, were not all considered patentable in spite of the fact that higher furnace temperatures with resultant increased production of as much as 50 per cent per sq. ft. of hearth were obtained—all with the expenditure of less fuel per ton of glass. Many of the ideas involved have since become more or less common knowledge among operators as well as furnace builders. But, in one year in the twenties, The Amsler-Morton Company redesigned and rebuilt thirty-six of these large regenerative melting furnaces in this country alone.

Another accomplishment of this period was the first successful continuous annealing process for heat resisting glass. This is of popular interest today because it may well be said that AMCO first took heat resisting glassware out of the laboratory and put it into millions of kitchens. Special continuous melting furnaces for the manufacture of heat resisting and other unusual glasses have long been among AMCO products.

In 1926, Paul M. Offill joined the organization as vice-president. Mr. Offill had started his engineering career in a surveying corps of the M. K. & T. R. R. and continued with H. L. Dixon Company, Laclede-Christy Clay Products Company, and the Simplex Engineering Company—the last three closely associated with either the steel or glass industries.

The service of the company to the glass industry continued to expand and, in 1928, the entire business of the James W. Cruikshank Engineering Company was acquired.

In the meantime, several glass manufacturers were developing the modern method of manufacturing plate glass by rolling it continuously between water cooled rolls—direct from the molten "metal." AMCO contributed to this process by devising a practical continuous roller bottom annealing lehr that utilizes the sensible heat in the glass itself in such a manner that additional fuel is not required to maintain the annealing temperature cycle.

To look after the business its accomplishments attracted from foreign countries the company, during the years 1928 to 1930, established offices in Sheffield, Paris, Barcelona, and Berlin. Between that period and the start of the present war, more than a hundred AMCO glass melting furnaces and many more AMCO unit portable annealing lehrs were placed in service in European factories. In more recent years all business outside continental United States has been handled by Amsler-Morton International, Incorporated, of which Mr. Geer is president and Mr. Morton, managing director. Representation is now maintained through agents—some of whom are manufacturers—in London, Sheffield, Paris, Prague, Milan, Athens, Cairo, Calcutta, Capetown, Singapore, Tokyo, Mexico City, and Buenos Aires, although many of these are inactive under existing political conditions. However, the current year found wide variety of work in progress in Canada, Uruguay, Argentina, Chile, and Bohemia.

In the early thirties consolidations began to reduce markedly the number of operating companies in the glass industry in United States, and when it became unlawful, under the NRA, to extend manufacturing facilities, the company began to think again of possibilities for service to other industries. Furnaces have been designed and licensed for the sodium silicate (water glass) industry, the production of mineral wool continuously, and for other miscellaneous purposes during the past decade. But, in view of the early background, it was natural to turn back to steel as the largest field for the organization's accumulated experience and understanding in the field of heat application and salvage.

A survey of the steel industry disclosed an apparent neglect of that important step which comes between the manufacture of the steel and its primary rolling into blooms and slabs—namely, the soaking pit. The productive capacity of the open hearth had been increased, and modernized rolling mills were demanding more and more properly heated ingots. But it seemed that the old soaking pit shops could not meet the demands being made on them even though every available square foot of building area were utilized. When the existing pits were forced the ingots were burned—increasing finishing costs; pit maintenance costs also went up, and these, together with the losses involved in consequent excessive bottom making, soon brought these forced operations to the point of diminishing returns.

This situation was recognized as an opportunity and the company proceeded with an intensive study of ingot heating furnaces which was to have far-reaching results.

Several attempts had been made from time to time to introduce the AMCO recuperator to the steel industry and some installations were made in the late twenties on both new and existing heating furnaces. But the steel mill furnace builders of the day were not enthusiastic about it, and most operators were distrustful of the staying qualities of any refractory recuperator. The company, however, after more than ten years' experience, knew that its recuperator, when properly installed, could be relied upon even in rigorous steel mill service and naturally wanted to incorporate in its ingot furnace designs the benefits of the recuperative system.

The encouraging and beneficial device of experienced steel mill operators and engineers assisted in defining the ingot heating problem in all its ramifications. One of the first considerations was to set up a furnace design that would permit replacing the more or less standard type soaking pits row for row. Further, and more important, the ingot setting capacity per row had to be appreciably increased—but not, however, beyond the reach and capacities of existing ingot handling cranes and buggies. All these requirements were met and the general usefulness of the AMCO design was further enhanced by adapting it for all gaseous industrial fuels as well as for fuel oil. In this connection, existing automatic furnace temperature and combustion

controls were investigated and a combination established which included some very desirable features not previously utilized in ingot heating practice. The conception of the AMCO furnace as a "machine for heating" was continually emphasized during the development period.

The AMCO recuperative ingot heating pit furnace that was finally evolved provided space for setting from twenty-five to fifty per cent more tons of ingots per row than can be set in the old regenerative pits. The ingots are set vertically and symmetrically around the walls of the pits, the fuel is applied through a carefully calibrated port in the center of the hearth, and the waste gases are removed through other ports in the bases of the walls on two sides. From these ports the waste gases pass down through the tubes of the recuperators and thence through ducts to the stack. The combustion air, after being blown into the base of the recuperators, and having passed around the heated vertical tubes, is gathered into horizontal flues under the hearth which carry it to the burner port in the center of the hearth. The entire fuel and combustion system is short-coupled and compact. The middle of each pit is a combustion chamber in which combustion takes place parallel to the longitudinal axes of the ingots so that the fire does not impinge against the ingot surfaces. Each pit is equipped with a completely sealing flat arch cover and the covers are handled by a specially developed electrically operated carriage or crane operating on rails flush with the tops of the pits.

This solution of the ingot heating "bottle neck" has proven unusually acceptable to the steel industry—more than a hundred AMCO furnaces have been ordered since the first installation was made in 1936.

Early in 1935, recognizing a need for general administrative supervision of its expanding engineering work, the company engaged Karl W. Gass as chief engineer. During the greater part of his more than twenty years' practice prior to joining this organization, Mr. Gass had enjoyed a broad engineering experience with United Pump and Power Company, Chester & Fleming, Consulting Engineers, Fort Pitt Engineering Company, and elsewhere.

Between 1935 and 1941, the usefulness of the AMCO organization to the steel and glass industries has grown more rapidly than ever before. Several complete glass factories have been engineered and constructed here and abroad. Steel heating furnaces of various types in addition to recuperative pit furnaces have been built in considerable numbers. Side door furnaces for plate mills and forging shops, car bottom furnaces for heating and annealing, special double compartment gun forging furnaces, and special pit type reheating and heat-treating furnaces for large forgings, as well as continuous heating furnaces of the pusher and circular rotating hearth types, constitute part of the company's contribution to the armament programs in both the United States and Canada.

The last mentioned furnaces are perhaps of special interest because they incorporate principles not previously utilized in continuous heating. In developing the heating cycle for cold steel in the batch type operation of the AMCO pit furnace, it was found that approximately seventy-five per cent of the heat required by the ingots could be absorbed by the steel in the first twenty-five per cent of the heating time. The increased yield resulting from this heating principle was so impressive that studies were made of means to obtain similar results in other types of heating furnaces. The principle was first applied to a side door plate mill ingot heating furnace with resultant dry hearth, reduced fuel consumption, and an increased yield of four per cent of finished plates.

To apply this principle to the continuous pusher type and rotating hearth type furnaces requires a somewhat radical departure from traditional practice—nothing less than reversing the entire fuel system by placing the main burners at the point where the cold steel is charged into the furnace instead of at the discharge end. An opportunity was created to build a 14 ft. x 30 ft. continuous pusher type furnace along these lines, to heat two rows of 12 in. to 17 in. thick ingots. The operating results obtained with this furnace justified all the predictions made for it and the company then received contracts for two 20 ft. x 60 ft. continuous recuperative slab heating furnaces and two 24 ft. mean diameter rotating hearth shell billet heating furnaces—all incorporating the principle of applying the heat when the steel can absorb it most rapidly.

In the course of accepting all these additional responsibilities, the AMCO organization has been expanded apace. Mr. Gass was made vice-president in charge of engineering in 1939, and Raymond C. Whitney became chief engineer at that time. Mr. Whitney had joined the company in 1936 after service with McClintic-Marshall Construction Company and The H. L. Dixon Company.

Assisting the chief engineer are Raymond C. Schnuth in the metallurgical field and L. J. Hartle in glass plant work. Frank H. Graham has charge of furnace operations and Carl L. Herman heads up the construction force. Edwin G. Smith is combustion and control engineer, Henry W. Tross has charge of structural steel and concrete design, Karl Yaromey of mechanical work, and J. P. Cromie, Jr., of piping and controls. H. E. Metcalfe is chief estimator. Thomas E. Roop has charge of purchasing, assisted by J. R. Payne. Miss C. O'Donnell is assistant treasurer.

During recent years considerable attention has been given to the development of modern systems for the production of pulverized coal and its application to industrial furnaces. This work is being handled by C. F. Herington, who has enjoyed many years' experience in the field, and who wrote one of the earliest textbooks on the subject. A number of notable pulverized coal installations have been made in connection with both melting and heating furnaces.

An affiliated company which renders a rather unique service is the G.M.S. Corporation, the activities of which are in charge of Theodore H. Sloan. Mr. Sloan has long been a designer of automatic machinery and is particularly well-known in the glass industry for which he has devised many outstanding machines for the manufacture of lamp bulbs, containers, and tableware as well as for automatically decorating these products. The ingenuity of the G.M.S. staff has produced many new and useful inventions which are being utilized by various industries.

Although too busy to spend much time in retrospect, The Amsler-Morton Company can look back over the twenty-five years that have elapsed since it was formed in 1916 with the satisfaction of knowing that at least a good foundation has been built for greater usefulness in the field of industrial engineering—a usefulness that takes nothing for granted, but always is striving with determination to make the discoveries of science more helpful to man.

FROM THE
TECHNICAL
LIBRARY
OF
KOPPERS
THE INDUSTRY THAT SERVES ALL INDUSTRY

HOW TO SOLVE SHAFT MISALIGNMENT PROBLEMS

KOPPERS ALL-IRON GATE VALVES

HOW TO TRANSPORT MOLTEN METAL AT LOW COST

KOPPERS COAL FOR COKE PLANTS

HOW TO REMOVE AND RECOVER H_2S

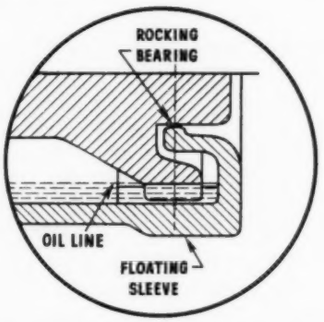
"Here's what sold the Big Boss on FAST'S COUPLING for our equipment"

"When the Big Boss said, 'Why do you insist on Fast's?' this dust-proof feature convinced him. In our operations, couplings have to run and keep on running in dusty atmospheres. The only protection is a *permanent* seal, and we get it with 'Fast's'."

A self-aligning coupling must be protected by a film of oil to prevent wear of the load-bearing surfaces. If dust or dirt works into this oil, it makes a paste-like abrasive that causes failure. Fast's couplings are positively sealed by the rocking bearings which make precise metal-to-metal contact, and are in the one position where they form permanent dust and moisture-proof seals.

To avoid danger of coupling trouble, specify *genuine* Fast's Couplings on the machinery you purchase.

KOPPERS COMPANY
BARTLETT HAYWARD DIVISION
BALTIMORE, MARYLAND



This illustration shows Fast's construction, and indicates the dust-proof, all-metal rocking bearings. Notice that no perishable materials—leather, cork or composition packing—are used. There are no weak points in Fast's design to cause failure . . . and only 'Fast's' can offer the metal-to-metal seal.

a K O P P E R S *product*

Fill out and mail

KOPPERS COMPANY
7316 Koppers Bldg., (19) Pittsburgh, Pa.

Please send me the literature checked:

Name.....

Title.....

Company.....

Address.....

- ☐ "Fast's Self-aligning Couplings"
- ☐ "Koppers All-Iron Gate Valves"
- ☐ "Hot Metal Transfer Cars"
- ☐ "Koppers Coal for Coke Plants"
- ☐ "How to Order Piston Rings"
- ☐ "Piston Rings for Compressors"
- ☐ "Piston Rings for Diesel Engines"
- ☐ "D-H-S Bronze for the Steel Industry"
- ☐ "Ar-Moored Ties"
- ☐ "Phenolate Gas Purification Process"
- ☐ "Seaboard Gas Purification Process"
- ☐ "Light Oil Refining"

The *heart* of the Farval System is the *soul* of simplicity

—because it has but two moving parts—contains no springs—no check valves—is fully hydraulic in its operation and will successfully distribute either oil or grease.

The Farval Dualine Valve is also fully adjustable to provide delivery of the exact amount of lubricant required by each individual bearing. Further, each Valve carries its own Tell-Tale Indicator to show that the job is done.

Thus Farval measures out the *correct amount* of lubricant, discharges it under high pressure to each bearing from one safe, central point—and not a bearing is missed.

Because of its simple design you can depend upon Farval to *maintain your peak production* in these critical times. Farval will also quickly pay back its cost by:—reducing power consumption as much as 30%—increasing life of bearings up to 10 times—lowering maintenance cost by 75%—prolonging life of equipment indefinitely.

The Farval Corporation, 3278 East 80th Street, Cleveland, Ohio.

Affiliate of The Cleveland Worm & Gear Company, Manufacturers of Automotive and Industrial Worm Gearing.

In Canada: PEACOCK BROTHERS LIMITED

Farval on Minster 50-8-84 Double Crank Press

FARVAL

CENTRALIZED SYSTEMS OF LUBRICATION

ITEMS OF INTEREST

H. C. Swartz, formerly general foreman, cold roll strip department, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania, has been advanced to the position of assistant superintendent of that department, succeeding the late Harvey C. Castle. Mr. Swartz, who attended the Glenville Normal School, has been actively identified with the flat rolling division of the steel industry since 1929. He has successively been associated with the Wheeling Steel Corporation, Inland Steel Company, and Bethlehem Steel Company. Mr. Swartz is an active member of the Association of Iron and Steel Engineers.

Charles D. Mills has been appointed manager, raw materials, fuel and power division, Pittsburgh district Carnegie-Illinois Steel Corporation, succeeding **C. B. Getsinger** who was recently appointed supervisor of fuel and power of Carnegie-Illinois.

Mr. Mills was born at Jamaica, Long Island, August 25, 1896, and attended public grade and high schools of Montclair, New Jersey. He was graduated with a degree in civil engineering from the Carnegie Institute of Technology in 1919 and immediately joined the engineering department of the former Carnegie Steel Company at New Castle, Pennsylvania. He became efficiency engineer at the New Castle plant later in the same year and in 1932 came to the general offices of the company in Pittsburgh as a special engineer. For the period from March, 1933 until December, 1935, he was fuel engineer at Clairton Works. He returned to the Pittsburgh offices in December, 1935 and in June, 1936, was named special engineer in the raw materials, fuel and power division.

C. M. Maratta, maintenance engineer for the Timken Roller Bearing Company since 1921, has been appointed chief works engineer, succeeding the late W. C. Makley.

Mr. Maratta served as power plant inspector of the Pennsylvania Railroad for seven years, draftsman for Westinghouse Electric and Manufacturing Company for four years, and joined the Timken company as a draftsman in 1917.

Walter F. Green, who has been with the Timken Engineering Department since 1935, becomes assistant works engineer.

Putney L. Wright, with Timken since 1938, will be plant engineer.

H. H. Rothrock, formerly head of the Industrial Engineering Department of the University of Pittsburgh, recently assumed his new duties as assistant to the chief industrial engineer of Carnegie-Illinois Steel Corporation.

Mr. Rothrock, a 1918 graduate of the Pennsylvania State College, served in the Coast Artillery of the United States Army during World War I. He joined the Westinghouse Electric and Manufacturing Company in 1919 and later became director of wage incentives. He joined the faculty of the University of Pittsburgh as professor and head of the Department of Industrial Engineering in 1933.

Joseph M. Marshall, Jr., has been appointed district engineer of the American Institute of Steel Construction with headquarters at Atlanta, Georgia. Mr. Marshall will represent the Institute in the territory embracing Virginia, Eastern Kentucky, North Carolina, South Carolina, Tennessee, Georgia, Alabama and Florida.

Prior to joining the Institute, Mr. Marshall was engineer inspector for the PWA in Georgia. He was graduated in Civil Engineering at Virginia Military Institute, and was engaged in construction work with the Seaboard Air Line and the Pennsylvania Railway. Mr. Marshall served as captain in the Eleventh Engineers in France from July, 1917 to January, 1919, and after the first World War was employed as field engineer for the Portland Cement Association.

R. S. Lynch, superintendent of the Stainless Division at Canton, Ohio, and the Enduro Stainless plant at Massillon, Ohio, both of Republic Steel Corporation, has been recently named divisional superintendent of the Massillon Steel Division, retaining also supervision of the Massillon stainless plant. Mr. Lynch was born in Vandergrift, Pennsylvania, and attended Ohio State University. From 1921 to 1924 he acted as first helper in the open hearth of the United States Steel Corporation at Vandergrift. He next became associated with United Alloy Steel Company in Canton, working on the blast furnace and later on the electric furnace. Following the merger of United Alloy with Central Steel Company, he was transferred to the Sales and

H. C. SWARTZ

"new assistant superintendent cold rolled strip department

Jones & Laughlin Steel Corp., Pittsburgh, Pa."

R. S. LYNCH

"to head Massillon stainless and steel division plants of Republic Steel Corporation"

Service Department, and in 1930, he was appointed assistant superintendent of the Polishing Department. In 1939, he was made superintendent at the Stainless Division at Canton, and of the Enduro plant at Massillon.

R. F. Horn, divisional superintendent of the Stark Sheet Division and of the Massillon Armor Plate plant, has received the additional appointment of divisional superintendent of the South Stainless Division at Canton. Mr. Horn was born in Dover, Ohio, educated in Hamilton, Ontario, and in 1911 became a chemist for the Steel Company of Canada. From 1914 to 1918, when he went into the Army, he was assistant superintendent of the Seneca Iron and Steel Company, Blaisdell, New York. Upon his return from the service, he joined the Canton Sheet Steel Company as assistant superintendent. In 1923, he became chief clerk of the Sheet Mills of the Weirton Steel Company, and 1928, was promoted to plant manager of the Sheet Mill. He joined Republic Steel Corporation in 1931 as divisional superintendent of the Stark Division and earlier this year was appointed divisional superintendent of the Armor Plate plant.

George W. Anderson has been appointed Pittsburgh district representative of the Tool Steel Gear and Pinion Company succeeding the late John D. Biggert. Mr. Anderson was graduated from the University of Illinois in 1925 with a degree in Industrial Engineering.

Prior to joining the Tool Steel organization in September of 1936 as a sales representative in the Chicago territory, Mr. Anderson was employed in the operating and mechanical engineering departments at the South Works of the Carnegie-Illinois Steel Corporation.

Arch R. Smith has been appointed sales manager, Ready-Power Company, Detroit, manufacturer of gasoline-electric power units. Mr. Smith formerly was manager of industrial sales for Continental Motors Corporation.

Mr. Smith is a member of the Association of Iron and Steel Engineers.

Harry B. Lose has been appointed superintendent of construction for Koppers Company, Engineering and Construction division, it is announced by Joseph Becker, vice president of Koppers Company and general manager of that division.

Mr. Lose formerly was assistant superintendent. He succeeds Roy L. Smith, who died recently.

Theodore J. Kauffeld, who joined American Type Founders in March, 1940, as manager of the Product Division, was elected a vice president of the company.

Ross O. Laub has been appointed plant industrial engineer, sheet and tin mill, Carnegie-Illinois Steel Corporation, Gary, Indiana, succeeding **Howard J. Stephens,** who has been transferred to the company's Pittsburgh office.

W. L. Schneider has been appointed to the position of vice president of sales of the Falk corporation. At the same time, the company announced the appointment of **T. F. Scannell** to sales manager, and **J. B. Kelley** to assistant sales manager.

Warren Gilman Jones, president of the W. A. Jones Foundry and Machine Company, Chicago, succumbed to a heart attack and passed away at his home in River Forest, Illinois.

Warren G. Jones was very well known in industrial and engineering circles. He was born in Chicago in 1890 and entered his father's firm in 1910, and had served as president of that company since 1925.

GEORGE W. ANDERSON

"will represent Tool Steel Gear & Pinion Company in Pittsburgh district"

"3C" BULLETIN 102 Type CHL Crane Hook Limit Switch effectively limits the upward travel of Crane Hooks.

On either A.C. or D.C. Crane Hoists, when operated by the Crane Hook, it does not of itself open the main motor circuit, but does open the coil circuit of a magnetic contactor in the main motor circuit.

This husky switch, complete with counterweight and cable, is built for heavy duty with a minimum of maintenance.

And how it's welcomed by maintenance men! All parts easily accessible—and all contact wearing parts interchangeable with similar parts in "3C" Bulletin 100 Type RD Master Switches, Bulletin 101 Type FS Foot Switches, Bulletin 102 Type CL Cam Limit Switches, Bulletin 102 Type HL Hatchway Limit Switches and Bulletin 102 Type TL Track Type Limit Switches.

Completely descriptive "3C" Bulletin 102 Type CH is yours for the asking.

CONTINUE TO ROLL WITH CLARK CONTROL

THE CLARK CONTROLLER CO.

1146 EAST 152ND ST. CLEVELAND, OHIO